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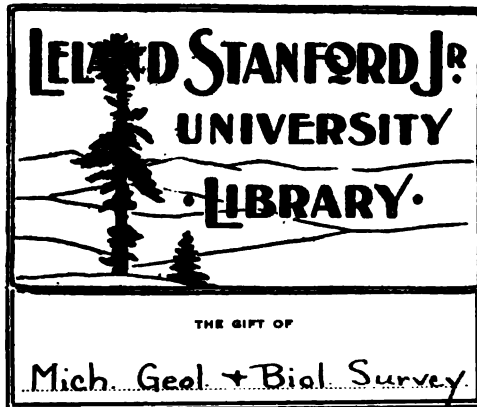
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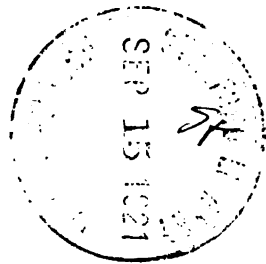
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MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY.

**Publication 19.**  
**Geological Series 16.**

---

**MINERAL RESOURCES OF MICHIGAN**

WITH

**STATISTICAL TABLES OF PRODUCTION  
AND VALUE OF MINERAL PRODUCTS**

FOR

**1914 AND PRIOR YEARS.**

WITH A TREATISE ON MICHIGAN COPPER DEPOSITS BY  
**R. E. HORE.**

PREPARED UNDER THE DIRECTION OF

**R. C. ALLEN**

DIRECTOR, MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY



PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE BOARD OF  
GEOLOGICAL AND BIOLOGICAL SURVEY FOR 1914.

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LETTER OF TRANSMITTAL.

*To the Honorable, the Board of Geological and Biological Survey of the  
State of Michigan:*

Gov. Woodbridge N. Ferris.

Hon. Wm. J. McKone.

Hon. Fred L. Keeler.

Gentlemen:—Under authority of act number seven, Public Acts of Michigan, Session of 1911, I have the honor to present herewith Publication 19, Geological Series 16, the fourth of a series of annual statements of the production and value of the mineral products of Michigan, with a special article by R. E. Hore on Michigan Copper Deposits.

Very respectfully,

R. C. ALLEN,

*Director.*



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**PART I. METALLIC MINERALS.**

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**MICHIGAN COPPER DEPOSITS.**

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**REGINALD E. HORE.**

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## CHAPTER I.

### LOCATION OF THE COPPER MINES.

Michigan's copper mines are located in the northwestern part of the state close to the south shore of Lake Superior. Most of them are in Houghton and Keweenaw counties on Keweenaw Point and the others are in Ontonagon County, which adjoins Houghton County on the south and west.

The district is easily reached by rail from the south, east and west. From Chicago trains to Houghton and Calumet are run by the Chicago, Milwaukee and St. Paul and the Chicago and Northwestern Railways. These enter the Copper Country on the tracks of the local railway companies, the Copper Range and the Mineral Range. From Sault Ste. Marie, St. Ignace and Duluth the copper mines are reached by the Duluth, South Shore and Atlantic Railway.

Keweenaw Point is also readily accessible by steamer. Portage Lake and a ship canal afford ready passage for the lake boats across the point and Houghton is a regular port of call for all passenger steamers running between Duluth and Sault Ste. Marie. The unusual transportation facilities are an important factor in the Michigan copper industry. Fuel and supplies from lower lake ports are brought to the mines at low cost.

Most of the copper produced is from Houghton County; but Keweenaw and Ontonagon also make important outputs and the richest of the younger mines, the Ahmeek, is in Keweenaw County. The deepest mines, the Calumet and Hecla and the Quincy, are both in Houghton County. According to B. S. Butler of the U. S. Geological Survey, 82.2% of the copper produced by Michigan mines in 1912 was credited to Houghton County. In the early days of the industry the chief production was from fissure-vein mines in Keweenaw County and bedded-vein mines in Ontonagon County.

Most of the important producers of today are located on a portion of the Copper Range about 25 miles long, extending from Painesdale in Houghton County to Mohawk in Keweenaw County. In order from southwest to northeast are the following well known mines: Champion, Trimountain, Baltic, Atlantic, Superior, Houghton, Isle Royale, Hancock, Quincy, Franklin, Osceola, LaSalle, Calumet and

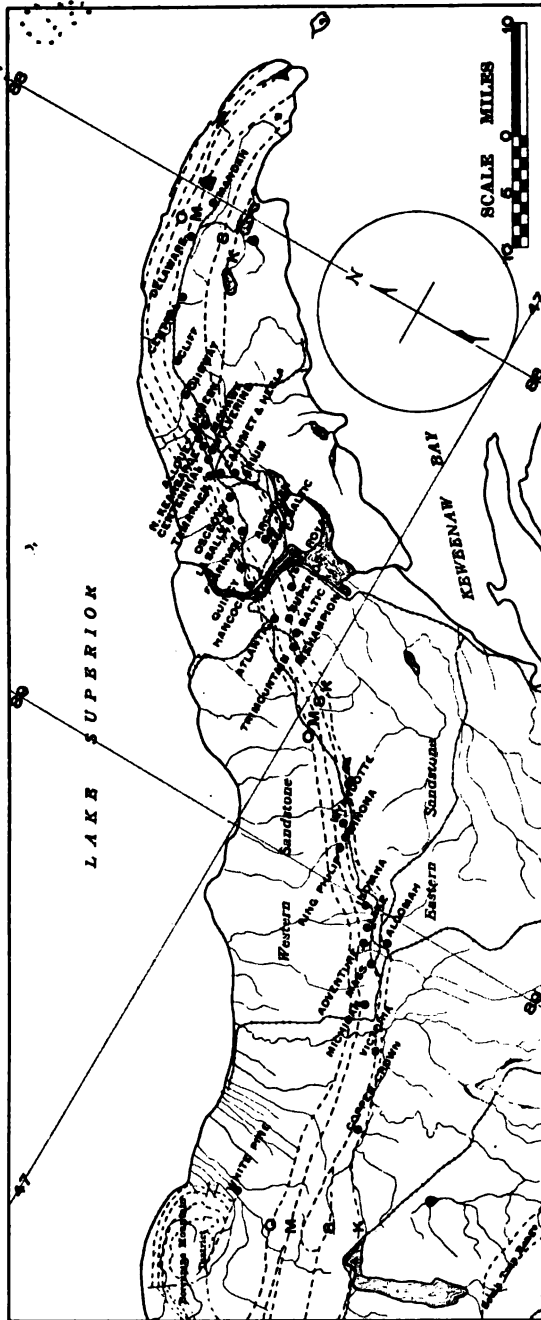


Figure 1. Outline map of Keweenaw Point showing location of mines.

Hecla, Tamarack, Centennial, South Kearsarge, Wolverine, North Kearsarge, Allouez, Ahmeek, Mohawk and Ojibway. Further southwest in Ontonagon County are the Lake, Mass, Adventure, Michigan and Victoria mines. Other active properties in Houghton County are Winona, Wyandot, New Baltic, New Arcadian, St. Louis, Laurium, Oneco and Naumkeag. In Ontonagon County shafts have been started and development work carried on at South Lake, North Lake and Indiana properties. In the Porcupine Mountain district, further west, the White Pine mine is being thoroughly tested by the Calumet and Hecla Mining Co. In Keweenaw County the Keweenaw Copper Company is doing extensive exploratory work with diamond drills.

Among old mines once productive but now idle, are the Cliff and Central in Keweenaw County and the Minesota in Ontonagon County.





## CHAPTER II.

### STRUCTURAL FEATURES OF KEWEENAW POINT.\*

#### GENERAL GEOLOGY OF KEWEENAW POINT.

The Keweenaw peninsula has in its central part a plateau at an elevation of 400 to 600 feet above the lake level. From this the ground slopes down on either side, gradually towards the west and more abruptly towards the east. A valley occupied by the narrow arm of Portage Lake cuts across this plateau, and gives ready access for lake ships. Further out on the point the plateau drops away, and there is a short gap of lower land followed by two long ridges which extend with occasional gaps well out to the end of the point. The northern ridge is called the Greenstone Range, and the southern is known as the Bohemian Range.

The plateau and ridges along the central part of the peninsula are formed by the copper-bearing, Keweenawan formation, bedded igneous and sedimentary rocks dipping to the northwest, and striking with the general trend of the point. The western slope down to Lake Superior is formed by the upper members of the same series. The easterly part is formed by gently inclined Upper Cambrian sandstone, separated from the Keweenawan formation by a great fault which extends nearly the whole length of the point. The fault is from the evidence at hand supposed to be of the reverse type, the older series slipping up and over on the sandstone.

#### STRUCTURE OF THE COPPER-BEARING SERIES.

The Copper Range of Keweenaw Point is comparatively simple in its larger geological features. The outcrop shows but the eroded edge of one limb of a synclinal formation, which dips under Lake Superior and appears again on the north shore. The beds strike with the general trend of the shore line northeast. Near the extremity of the point the strike is almost due east, and at the very extremity the formation bends south of east. In following the range out towards the point, there is found a lessening of the inclination of the beds. In going from lower to higher horizons the same change in dip is found, the lower beds dipping more steeply than the upper ones. On follow-

\*In this chapter merely an outline of the structure is given. For details the reader is referred to the monograph by Dr. A. C. Lane published by the Michigan Geological Survey, Publication 6, Geological Series 4.

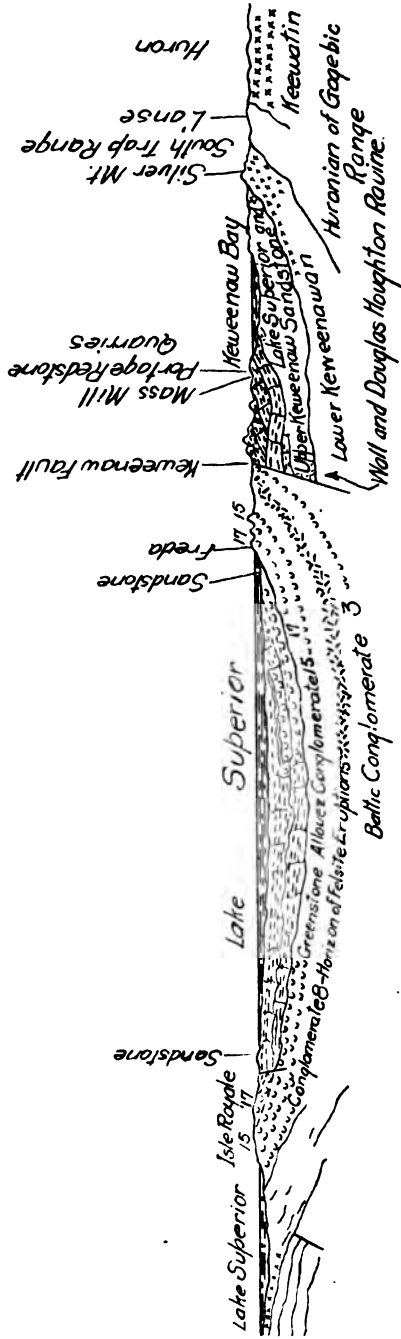


Figure 3. Cross section through Lake Superior from Huron mountains to Port Arthur (after A. C. Lane in Mines and Minerals).





ing down on the dip of a bed, there is found in all deep mines a lower angle of dip. At the Quincy Mine the dip of the lode near surface is about  $54^{\circ}$ , while a mile down the inclined shaft the dip is only  $37^{\circ}$ . At the Calumet and Hecla, the change in the same distance is very little, the inclination being  $38^{\circ}$  to  $39^{\circ}$  at surface and  $36^{\circ}$  to  $37^{\circ}$  at a depth of over one mile. At the Central Mine in Keweenaw county the dip decreases from  $27^{\circ}$  at surface to  $21^{\circ}$  in the lower levels. On the main copper range there are few marked divergences from the general structure as above outlined. The structure is illustrated by the accompanying section taken from Dr. Lane's monograph.

Changes in strike and dip and thickness of beds occur in the neighborhood of some intrusive masses. Recent work at the Lake and South Lake mines in Ontonagon county has shown the beds there to be sharply folded, so that a part of the formation is dipping south instead of northwest. Further west in the Porcupine Mountains, folding and faulting has made the structure locally complex.

#### FAULTING.

Faults are very numerous in the Keweenawan formation. The most important fault has brought the Keweenawan formation up against the Potsdam sandstone. In the northern part of Houghton County according to drilling records at the Mayflower property this fault dips to the west at a much smaller angle than do the beds of the Keweenawan formation. Beds at low horizons in the latter are probably cut off at no great depth; but none of the very productive lodes are very close to the sandstone here. Further south the dip of the fault is steeper.

There are instances where upper beds have slipped on lower beds great distances; but only in a few cases has the displacement been measured. Dr. Hubbard has estimated that one part may have moved on the lower part of the series about 2.7 miles north from its original position. In other cases a similar slide fault or "slide" has displaced upper beds downwards on lower beds for considerable, but unmeasured, distances.

Throughout the series there are frequently found thin beds of soft clay-like material or fluccan, which have probably been formed by beds sliding on one another in this way.

Besides these "slides" there are numerous faults where the fault plane cuts across the bedding. Where the amount of throw has been measured it is usually less than 100 feet, and most frequently it is so much less that displaced beds are picked up in the mines by a little widening of the drifts or by driving short cross cuts. Faults are

especially numerous in the parts of the series near the eastern sandstone. In some of the mines on the Baltic lode, which is at a low horizon, the rocks show innumerable small faults.

## CHAPTER III.

### THE COPPER BEARING ROCKS.

#### THE KEWEENAWAN ROCKS.<sup>1</sup>

The Keweenawan formation in Michigan is commonly divided into two series<sup>2</sup>, lower and upper. The lower is largely igneous, with occasional interbedded beds of sediment, and the upper largely sedimentary with some interbedded layers of igneous rocks. The division line between the two series is the base of the Outer Copper Harbor conglomerate. The copper bearing lodes are, with one exception, in the lower Keweenawan. The exception is a deposit in sandstone in the upper series.

The Lower Keweenawan of the Copper Range is chiefly made up of dark grey and brownish volcanic rocks. These occur in beds many of which are between 10 feet and 200 feet in thickness. Many others are thinner or thicker. With the dark colored volcanic rocks are imbedded reddish conglomerates and sandstones, ranging from mere seams up to beds of several hundred feet in thickness. In the horizon of the chief productive lodes, the sediments form only about seven per cent of the total thickness of the formation. In addition to the dark colored volcanic rocks, there are much smaller areas of light colored felsitic and porphyritic types, and more basic coarse grained intrusive masses. The felsites do not occur in the immediate vicinity of the chief copper lodes; but are common at both lower and higher horizons. Distinctly grained intrusive rocks, such as gabbros, occur in the Keweenaw series but are not found in the copper mines.

While the volcanic rocks of the Keweenawan are of many varieties, it is for most purposes unnecessary and often inconvenient to use different names for all the types. A simple classification such as that used by Dr. L. L. Hubbard, in Vol. VI of the Survey's publications has proven very satisfactory for many purposes.

<sup>1</sup>An exhaustive monograph on the Keweenawan rocks has been recently written by Dr. A. C. Lane and published by the Michigan Geological Survey. Dr. Lane describes the rocks in detail and his report is accompanied by a large number of maps and geological sections. In the following pages will be found some earlier descriptions of the copper-bearing rocks taken from publications that are not readily obtained. Dr. Lane's report can be obtained on application to the Director of the Michigan Geological Survey at Lansing.

<sup>2</sup>A third division is sometimes, and notably in a recently published monography by C. R. Van Hise and C. K. Leith of the U. S. G. S. made to include only the sediments found in some localities at the bottom of what is more commonly called the Lower Keweenawan. The rest of the Lower is then called Middle Keweenawan.



## L. L. HUBBARD'S CLASSIFICATION.

Dr. Hubbard defines\* these rock names as follows: "In the following pages I shall use the term *melaphyre* generically to cover the more basic and augitic effusive rocks, qualifying it by *doleritic* when coarse grained, *ophitic* when lustre mottled, *diabasic* when it discloses lath-shaped feldspars in an augitic matrix, and *amygdaloidal*, when it contains gas-formed cavities either empty or filled with foreign minerals. The term *porphyritic* will be used to designate rocks known to be of medium acidity, whether they carry feldspars visible to the naked eye or not. The word *trap*, commonly used by the miners, is a convenient field term and will include fine grained compact varieties of both melaphyre and porphyrite, where the exact character of the rock has not been determined and more often, perhaps, will be used in a still broader sense, to cover the entire Keweenaw series. The very fine grained and highly acid rocks, formerly also included under the term trap, will be called *felsite*, or when they carry feldspar or quartz crystals in some abundance, *porphyry*."

The doleritic, ophitic and diabasic melaphyres are called dolerites, ophites, and diabases respectively. This terminology is not altogether in accord with that of other districts, but it has been long in use in the copper country and has proven very useful. The rocks called ophites† are very common and easily distinguished from other traps. These rocks have been carefully described by Dr. Pumpelly, and are of special interest as almost all the amygdaloid lodes are parts of flows which in the less vesicular portions are ophites.

## A. C. LANE'S CLASSIFICATION.

A. C. Lane, in the introductory chapter of his recently published monograph on the Keweenaw series says‡ regarding nomenclature:

"The commonest copper bearing rocks are mainly old lava flows, and the usual type is much the same as any ordinary trap or basalt. \* \* \* We might call these flows *traps*, but time-honored usage discriminates the main massive part as *trap* from the originally porous upper part as *amygdaloid*. \* \* \* The term *gabbro* is kept for the deeper-seated intrusions. \* \* \* Most of those rocks which are generally fairly uniformly coarse in grain are *gabbro*. All the effusives are wholly or partly of the melaphyre type. So we continue to use the term *melaphyre* for the dark colored lavas generally and call the coarser streaks *doleritic melaphyre*."

\*Geological Survey of Michigan, Vol. VI, Pt. II, p. 11.

†For illustrations showing weathered surfaces, drill cores and thin sections, see Publication 6, Mich. Geol. Sur. A. C. Lane.

‡Publication 6 Michigan Geological Survey, 1909, p. 27.

Dr. Lane uses the term *ophite* for the rocks which Pumpelly called *lustre mottled melaphyres*, and restricts the term *diabase* to intrusive dikes and sills. The feldspathic porphyritic beds of the Ashbed group he calls *porphyrites* and their texture he calls glomerporphyritic.

#### R. PUMPELLY'S DESCRIPTIONS AND CLASSIFICATION.

R. Pumpelly gave a detailed description of the copper-bearing rocks as he knew them in 1873.\* His description is a remarkably good one and a large portion is here quoted as the original publication has been long out of print:

"In the immediate neighborhood of Portage Lake, the strata composing the 'Mineral Range' have a uniform trend of North 35° East, and a nearly equally regular dip of 55° to 60° to west north-west.

"The series consists of beds of melaphyre, varying in thickness from 20 feet to more than 100 feet, the demarkation being frequently defined by the amygdaloidal or epidotic character of the upper portion of each bed.

"At intervals, varying from a few yards to several thousand feet, beds of conglomerate occur intercalated in the series.

"This is the general character of the country near Portage Lake for a distance of about three miles, measured west north-west across the formation.

"The trappean rocks of Portage Lake occur uniformly in beds varying from a few feet to one hundred feet, or more, in thickness. Frequently an appearance of subordinate bedding is observable, arising perhaps from the existence of joints lying parallel to the place of stratification, which divide the rock into plates a few inches to several feet thick.

"The texture of many varieties varies from compact and sometimes porphyritic, through fine-grained subcrystalline or earthy, to coarse-grained and distinctly crystalline. In individual beds the texture is usually found to undergo a more or less gradual change from compact or granular at the bottom, to a vesicular or amygdaloidal condition, in the neighborhood of the hanging wall.

"Green of various shades is the dominating color, and next to this brown and dirty red. Light and dark green, mottled or speckled with brown; dirty brownish-green; reddish-gray; and dark green, almost black; are the usual colors.

"Even in the fresh state, these rocks may be easily scratched with a knife, but they are exceedingly tough under the hammer. The force which crushes a fragment often leaves the powder very firmly compacted.

\*Geological Survey, Michigan, Vol. I, Pt. II, pp. 7-8, 1873.

"The fracture is generally uneven, or hackly, to imperfectly conchoidal. They have an earthy odor often even without having been breathed upon.

"Some varieties yield a thick beard of a magnetic iron ore to the magnet while others contain very little of this mineral.

*Chief Constituents*—"The ingredients which are visible under the glass, and which seem to be common to all varieties, are a light green triclinic feldspar (apparently labradorite) and chloritic minerals of different shades of green. The magnet reveals a variable percentage of a magnetic iron. In some of the coarser grained varieties small jet black crystals apparently of augite or hornblende are occasionally visible. *The accessory minerals* observed, many or all of which are probably products of the alteration of the above constituents are:

"A brick-red foliaceous mineral resembling rubellan, [iddingsite?] occurring as very minute specks in some fine-grained varieties; it lends a soft rusty-brown appearance to the weathered surface and speckles the interior with red. Specular-iron in minute flakes, seemingly more frequent in the coarser-grained varieties. Calcite in seams and, more frequently, in grains and amygdules, especially in the amygdaloidal portion of the beds. Epidote rarely crystallized; most common in the amygdaloidal varieties, but frequently in seams and impregnations, and nearly always associated with quartz. Quartz which occurs in amygdules and seams and also as an indurating medium near the hanging-wall of many beds. Prehnite in amygdules and seams, mostly confined to the amygdaloidal portion of the beds. A chlorite-like mineral (delessite) soft, compact, amorphous, greenish black, sometimes altered to brick red, occurring in grains from pin-head to walnut size. A yellowish green soft earthy mineral, probably a green earth. Laumontite and leonhardite in seams and amygdules. Analcite in amygdules. Orthoclase in small crystals and massive, in amygdaloidal cavities. Native copper sometimes in fine impregnations in the fine-grained rock, also in the sheets in joining cracks, but chiefly in the amygdules, masses, sheets and impregnations which form the metalliferous deposits in the amygdaloids, where it is occasionally associated with native silver. Native silver. Datolite massive in the amygdaloidal portion of some beds, and also in small aggregations of microscopical crystals in the same positions.\*

*Essential Constituents of Melaphyres.*—"Everything goes to show

\*In addition to the minerals mentioned by R. Pumpelly, the following have been noted by Prof. A. E. Seaman in the Keweenaw rocks. Adularia, agate, anhydrite, algodonite, azurite, aragonite, argentite, amethyst, annabergite, amphibole, ankerite, garite, biotite, bornite, cerargyrite, chalcocite, chloanthite, crysocola, chalcopyrite, chlorastrolite, cuprite, covellite, clinocllore (?), dolomite, domeykite, fluorite, gypsum, hematite, iddingsite, jasper, koalinite, keweenawite, limonite, magnetite, martite, marcasite, malachite, melaconite, muscovite, mohawkite, niccolite, para-melaconite, pyrite, pyrrhotite, phillipsite, powellite, saponite, selenite, semiwhitneyite, serpentine, siderite, talc, thompsonite, wood, whitneyite and wollastonite.

that the normal, essential constituents of these rocks are, in their present condition, a triclinic feldspar, probably labradorite, and a ferruginous chlorite closely allied to delessite. This composition places these rocks among the typical melaphyres, the greater specific gravity of the Portage Lake varieties being accounted for by the fact that the specific gravity of delessite is 2.89, while that of ordinary chlorite ranges from 2.65 to 2.78.

"Although the name melaphyre is an unfortunate one, having been first used to designate an entirely different rock, and having been successively applied to others of very various characters, it is now the only distinctive name for the class we have under consideration. All the trap rocks and associated amygdaloids of Portage Lake are varieties of melaphyre.

"But I do not doubt that any one who will carefully study the melaphyres of Portage Lake, and compare them with their equivalents in Keweenaw County, will feel convinced that the melaphyre owes its distinctive character to a process of metamorphism, in which the chlorite resulted, largely or wholly, from the alteration of hornblende or pyroxene. In the more distinctly crystallized traps of Keweenaw County, the pseudomorphic occurrence of chlorite after the hornblende or pyroxene constituent of the trap, may be traced through all the stages to a complete replacement of the latter by chlorite.

*"The principal varieties of melaphyre on Portage Lake are:*

1. Coarse grained; in which the crystals of feldspar and grains of delessite are more or less distinct. The color is greenish-gray. It contains generally grains of magnetite and small tabular crystals of specular iron.

2. Fine-grained; the constituents, light-green or reddish triclinic feldspar and dark-green delessite, are sometimes distinguishable, but more generally they are not so. The usual color is grayish-green, but it sometimes is speckled with brown, through the presence of small flakes of rubellan; or mixed green and brown from the oxide of iron produced in the decomposition of some of the constituents. As a rule the greater the amount of rubellan the less there seems to be of magnetite. In some instances, especially in some of the beds east of the Isle Royale copper-bearing bed, the rock is fine-grained and subcrystalline, brilliant black-green, sometimes purplish; slightly shimmering; easily scratched with the knife; contains considerable magnetite, small pieces of rock adhering to the magnet. It weathers rusty gray.

3. Melaphyre-porphry; dark-green, often nearly black; compact, with perfect conchoidal fracture; very hard; contains minute crystals of triclinic feldspar.

### Amygdaloids.

"The amygdaloids are merely varieties of the melaphyre. On Portage Lake, they always form the upper or hanging-wall portion of beds of trap, into which they pass by a more or less gradual transition.

"It is rare that one finds a bed of trap which does not contain, here and there, scattered segregations of secondary minerals, especially delessite, but often calcite, laumonite, quartz, or chalcedony, or prehnite, occupying cavities which are often well defined and spherical or ovoidal, but sometimes wholly irregular in shape, and without definite wall. These enclosures usually become more frequent in ascending from the foot-wall of a bed toward the hanging-wall. The plane of demarkation between the amygdaloidal upper portion of a bed and the overlying rock is always well defined. Where they are sufficiently numerous to impress a distinctive character upon the rock, while at the same time the matrix retains the essential features, in regard to color and texture of the present trap, I have designated the variety amygdaloidal melaphyre.

### Amygdaloidal Melaphyre.

"All the varieties of melaphyre on Portage Lake are subject to this modification, but there is a considerable variation among different beds in regard to the nature of the minerals in the amygdaloidal cavities. In all the varieties amygdules of delessite, or calcite, or quartz coated with delessite, or again spots of epidote, occur here and there in the body of the rock. In some beds the rock is characterized throughout by the presence of laumonite in small amygdules and minute seams.

"In the belt occupying 1,000 feet or more on either side of the Isle Royale copper-bearing bed many of the beds assume towards the top amygdules of delessite and of green flinty mineral, resembling chrysoptase, coated with delessite. These are gradually succeeded nearer the top by ovoidal, lenticular, or irregular amygdules, from the size of a bean to several inches in diameter, of prehnite, greenish-white, or tinged with pink generally amorphous, but often with a radiating structure, and sometimes slightly impregnated with native copper.

"The portion of the bed nearest the hanging-wall is often highly amygdaloidal, while the matrix has at the same time a different degree of hardness, texture and color, and often a different mineralogical constitution from the parent trap. These varieties form the amygdaloids proper.

### Amygdaloids Proper.

"The amygdaloids are the most highly altered form of the melaphyre and present themselves under a variety of characters in different beds

and in different parts of the same bed. The colors of the matrix are different shades of brown or red, and of green, or of these mixed. The texture varies from fine-grained or sometimes subcrystalline to compact; and the hardness ranges from that of limestone to that of quartz.

"Two quite different kinds of amygdaloid occur on Portage Lake, both separately and intimately associated in the same bed, and are easily distinguished by their different colors, the one being brown and the other green.

*Brown amygdaloids.*—"The brown, which exhibits the amygdaloidal character in its highest development, has a chocolate-brown to dirty red matrix, which generally is easily scratched with the knife, but is sometimes indurated and hard; it has a fine-grained to subcrystalline texture, and now and then contains minute reddish crystals of feldspar, and fuses easily to a dark-green and somewhat magnetic glass.

"The amygdules in this variety are more generally spherical, but often somewhat irregular and connected, and more rarely long-cylindrical, and then usually perpendicular to the plane of bedding. The contents of these cavities, for they are very rarely empty, are laumonite, leonhardite, calcite, quartz, a soft green mineral (apparently green-earth), delessite (more rarely), native copper, epidote, prehnite, analcite, orthoclase. In places one, in others another, of these predominates; generally several are associated.

*Green amygdaloids.*—"The green variety is a very fine-grained to compact light grayish-green rock. It is generally very hard, striking fire under the steel. Its constituents are very largely free silica, and a green mineral which has been generally taken for epidote, but which is so minutely disseminated as to render it difficult of determination. Small pieces of the rock fuse easily on the edges to a dark enamel which gelatinizes with acids. These beds are called epidote 'veins,' and they are probably, in many instances, at least, an intimate mixture of quartz and epidote, though in otherwise nearly similar beds the green mineral is soft, and is probably either a green-earth or a chlorite. The cavities in this variety are often less regularly defined in shape than in the brown amygdaloid. The enclosed minerals are quartz, epidote, calcite, delessite, prehnite, laumonite, green-earth, analcite, native copper, orthoclase. "These two varieties of amygdaloids often occur together without any well defined lines of separation, the bed being made up of irregular masses of the two rocks. In places, however, the brown amygdaloid forms a band one to two feet thick on the hanging-wall, with a rather abrupt transition into the green amygdaloid underlying it; I have never observed the reverse.

"Some beds have an exceedingly mixed character; the amygdaloidal portions are associated with massive segregations of calcite, quartz

and epidote, and are traversed by seams and irregular veins of these minerals. This structure is especially noticeable in the beds worked for copper. A somewhat similar structure occurs in other beds on a smaller scale, giving to them a brecciated or even a conglomerate-like appearance, which seems, however, to be due to purely metamorphic action; the best example of this is in the 'Ancient Pit' bed, on the Shelden and Columbian property."

*Texture of amygdaloids.*—In a later article Dr. Pumpelly says\* of the amygdaloids: "The uppermost zone—the amygdaloid—in many beds is, in several respects, essentially different from the rest of the rock. In these instances, the matrix has a much finer texture, often quite aphanitic, even where the lower and pseudo-amygdaloid zones of the same bed are quite coarse grained and distinctly crystalline. The amygdules have generally a spherical or ovoidal forms, filling cavities with sharply defined walls. In some rare instances, the amygdules are long and cylindrical, and arranged perpendicular to the plane of bedding.

"In thin sections, the difference between the texture of the matrix and the texture of the lower zone of the same bed is very apparent. While the primary constituents, when preserved, do not differ apparently in quality, they are of much smaller size, and sometimes show an arrested development and microfluidal structure. Here, too, the amygdules have sharply defined, evenly curved contours, differing wholly in this respect from the pseudo-amygdules of the lower zones of the same bed. Often also the primary minerals of the matrix are much more minute in the immediate neighborhood of the amygdules than away from them, and their disposition seems also to have been influenced by the presence of the amygdaloidal cavity. The color of the amygdaloid matrix varies between different shades of dark greenish brown, chocolate-brown, dull light green, and brilliant light green. All these colors often occur in the same bed, or even in the same specimen, and, like the difference in hardness—from 3 to 7—are due to metasomatic changes.

*Scoriaceous amygdaloids.*—"There is one variety, the scoriaceous amygdaloid, which occurs less often than the others, but is always strongly characterized. It consists of true amygdaloid and sandstone curiously associated. The amygdaloid is in contorted forms, from an inch or less to several feet in size, with a sharply defined, often wrinkled surface, and wholly enveloped with sandstone. The glaciated surface of the outcrops of this rock often present at the first glance the appearance of a conglomerate, in which here the amygdaloid, there the sandstone, appears to form the cement. Thin sections show that we

\*Proc. Amer. Acad. Arts and Sci., Vol. XIII, 1878, p. 282.

have to do with a true sandstone of quartz and feldspar derived from quartz porphyry, and identical with that which forms the great sandstone beds of the copper series; and that the other constituent is a true amygdaloid.

"The conditions, as studied on the ground, indicate that these beds are volcanic scoriae, buried in the littoral sand. To this variety belong the famous 'Ash-bed' of the Copper-falls and Phoenix mines, and the beds worked in the Hancock and South Pewabic mines."

#### R. D. IRVING'S DESCRIPTION OF THE AMYGDALOIDS.

R. D. Irving says\* of the amygdaloids: "The flows of the finer-grained rocks are all commonly provided with upper vesicular portions, by the subsequent filling of whose vesicles, and the various degrees of alteration of whose matrices have been produced the manifold types of amygdaloid known in the Lake Superior region.† The coarse rocks—olivinitic and orthoclastic gabbros—are not furnished with amygdaloids save when tending to a distinctly finer grain than usual.

"Externally, the matrix of the amygdaloid is commonly quite different from that of the rest of the bed. This difference consists principally in greater denseness of grain, from solidification while much of the matter was not developed into distinct minerals. The difference is least, then, in the case of those beds whose lower portions are composed of some phase of the diabase-porphyrates, in which there is also a greater or less proportion of unindividualized matter. In some of these beds, especially when the rock is of the dense brownish kind with highly conchoidal fracture, above described, there is no perceptible difference between the matrices of the vesicular and non-vesicular portions of the bed; but more usually there is a great difference in this respect between the lower and vesicular portions of a flow. The internal changes to which an open vesicular substance, composed largely of a molecularly unstable material like glass, must always be liable, have greatly increased the difference, and have given rise, by the variation in the decomposition products, to a great variety of amygdaloids, which it would seem at first sight hard to place together.

"*Under the microscope* the matrix of the unaltered, or relatively little altered, amygdaloid shows nearly always much non-polarizing matter, commonly deeply stained with red ferrite. In this are developed needles of plagioclase to a greater or less extent, and often these needles

\*Mono. V., U. S. G. S.

†Pumpelly has spoken of the olivinitic fine-grained kinds, his melaphyres, as less commonly provided with amygdaloids than are the olivine-free diabases of the ordinary type, but in my observations this is only true when the melaphyres have a distinct tendency to become coarse-grained, as in "The Greenstone" of Keweenaw Point. When they are fine-grained they appear to have amygdaloids quite as frequently as the olivine-free kinds.



seem to be but microliths arrested in the process of aggregation into crystals.\*

"Augite particles occur, but are usually relatively sparse, and frequently fail entirely. Very often there is a fluidal structure brought out in the arrangement of the plagioclase microliths and the other particles, and in many cases the flowage direction is found to coincide with the longer axes of the elongated vesicles. The vesicles themselves, filled or empty, as the case may be, are always sharply outlined in the thin section, and there is immediately about them a crowding of the plagioclases and ferrite particles, as if by pressure in the cavity. Moreover, the individualized minerals, as Pumpelly has shown†, are often more minute in the vicinity of the vesicles than away from them. Porphyritic feldspars, macroscopically visible, are frequently developed in the matrix of the amygdaloids—so far as my observation has gone they are at least as often present as not—and in this respect we have yet another affinity between the amygdaloids and the non-vesicular diabase-porphyrates.

"*Macroscopically*, the vesicles are seen to be commonly filled with secondary minerals—one or more of 'calcite, chlorite, epidote, quartz, prehnite, laumontite, copper, orthoclase, or their products of alteration.'‡ Often, however, I have observed the vesicles empty, either from the removal of the amygdules or from their having always remained empty. The walls of these empty cavities are commonly found to be smooth and dense, apparently from the pressure of the confined vapor.

*Alteration*—"Although a large number of sections of amygdaloids were cut with this object in view, I have not been able to find the time to extend the studies, so ably begun by Professor Pumpelly, of the changes which have brought about the fillings of the vesicles and the various stages of alteration of the matrix. He sums up the results of his studies on the alterations of both pseud-amygdaloids and the true vesicular amygdaloids in the following table, which is designed to show the course and final results of the most common process of alteration:

Pseud-amygdaloid stage . . . . .	{	I. Hydration of chrysolite, when present.
		II. Change of augite, loss of lime, and partial loss of iron and magnesia.
		III. Change of feldspar to prehnite, and formation of prehnite pseud-amygdaloids.
		IV. Change of prehnite to chlorite.
		IVa. Change of prehnite to orthoclase.

\*R. Pumpelly, "Metasomatic Development," p. 282, U. S. Geol. Sur., Monograph V.

†Ibid., p. 283. U. S. Geol. Sur., Monograph V.

‡R. Pumpelly, *Geology of Wisconsin*, U. S. Geol. Sur., Vol. III, p. 31.

- Amygdaloid stage. {
- I. Filling gas vesicles with prehnite, or other minerals. Change of matrix to ferruginous prehnite.
  - II. Change of the prehnite, in places, to Chlorite; in others, to calcite and green-earth; in others, to epidote and calcite.
  - III. Entrance of quartz, filling all the interstices and replacing the calcite.

The following are Pumpelly's comments on this table: "This is the broader history. Orthoclase is here, as in pseudo-amygdaloid, of sporadic occurrence and a product of the prehnite.

"The changes under II may affect only the amygdules, or, if the matrix was prehnitized, it applies to the whole mass of the amygdaloid. It does this in such a manner that, where carried to its extremes, considerable portions of the bed have lost every semblance of an amygdaloid and consists now of chlorite, epidote, calcite, and quartz, more or less intimately associated, or forming larger masses of the most indefinite shapes and merging into each other. Sometimes portions of partially altered prehnite occur. In places considerable masses of rich brown and green fresh prehnite filled with copper occur; but as a rule this mineral has given way to its products.

"To this process the copper-bearing beds of Portage Lake owe their origin. Considerable portions of these beds are but partially altered amygdaloids, containing amygdules of prehnite, chlorite, calcite, or quartz, with more or less copper; other portions are in the condition described above.

"This, too, (II. and II.), appears to have been the principal period of concentration of the copper. In the still amygdaloidal portions, this metal was deposited in the cavities and in cleavage-planes of some minerals, and replaced calcite amygdules, etc. But in the confused and highly altered parts of the bed it crystallized free, where it had a chance; more generally it replaced other minerals on a considerable scale. It formed, in calcite bodies, those irregular, solid, branching forms, that are locally known as horn-copper, often many hundred pounds in weight; in the epidote, quartz, and prehnite bodies, it occurs as thread and flake-like impregnations; in the foliaceous lenticular chloritic bodies, it formed flakes between the cleavage-planes and oblique joints, or in places—and this is more particularly true of the fissure-veins, which we are not now considering—it replaces the chloritic, selvage-like substance till it forms literally pseudomorphs, sometimes several hundred tons in weight.

"When the amygdaloid has arrived at the condition we have been

describing, it assumes some of the characters of a vein, in that although it presents no open fissure it contains greater or smaller masses of calcite and other minerals that are easily replaced by an intruder. To this period, probably belongs the replacement of calcite by datolite; and here, also, the rather rare occurrence of analcite crystals and the pseudomorphs of orthoclase after these.

"As I have already remarked, the pseudo-amygdaloids are merely altered forms of the same rock as the lower zone. There seems to be a definite limit at which this progressive change stops, and that is when all augite is changed to its green pseudomorph and a large percentage of the rest of the rock consists of pseudo-amygdules of delessite, and partial pseudomorphs of this after plagioclase. The occurrence of epidote and quartz is not general, and is confined to scattering pseudo-amygdules, in which these minerals have succeeded prehnite, perhaps in the local absence of the conditions necessary to produce the usual delessite.

"Thus I conceive that the extent of the change to the pseudo-amygdaloidal form is conditioned essentially by the amount of augite present, to supply first the lime necessary to aid in changing the plagioclase to prehnite, and next the iron and magnesia to form the delessite, whether by acting directly on the feldspar substance or on the prehnite.

"The amygdaloids proper were, probably, both structurally and chemically, somewhat different from the lower zone, in that it is reasonable to suppose that, in addition to being more or less porous, they contained a greater or less amount of amorphous base, which is more easily altered than a crystalline aggregate. But, from whatever cause, the amygdaloids have, as we have seen, been capable of much greater changes than the lower zone. In them the tendency is undoubtedly towards the formation of quartz, chlorite and epidote rocks, as a more stable limit, through the mediation of prehnite and calcite."

#### A. C. LANE ON AMYGDALOIDS.

A. C. Lane says\* of the amygdaloids: "The top of each flow is naturally more likely to be open in texture, full of bubbles, and thus more porous and easily crushed. Such tops are known as amygdaloids, and they are sought by the explorer, for in the filling of their pores the copper may be concentrated. A real amygdaloid top to an independent lava flow is likely to be fairly persistent and has numerous round walled cavities often filled with some white mineral. Its top is commonly pretty well marked while its base fades out gradually into the underlying not bubbly compact part of the flow which is distinguished as 'trap.'

\*Pub. 6, Keweenaw Series of Michigan, Mich. Geol. Sur., 1909, p. 28.

"But just as modern lavas or streams of slag are liable to gush over and envelop cooled crusts or crystallize and leave cavities like those lined with melilite crystals in the pots of slag from the copper cupola furnaces, so was it with those old lavas. Amygdaloidal streaks often run down into the trap, and amygdaloid spots, bombs or inclusions, characteristic under the Wolverine sandstone, are often found in the solid trap, and coarsely and openly crystallized 'doleritic'\* streaks are also found especially in very thick flows, and between the crystals, calcite, etc., may form giving these streaks also a spotted and amygdaloidal appearance.

"The trap under the amygdaloid, the foot wall trap, is liable to be relatively lighter and more feldspathic, feldspar being the lighter mineral. The feldspar is generally oligoclase of labradorite, and appears as rice-like grains if the rock is coarse enough. The darker interstitial matter is mainly augite or its alteration product, chlorite. The olivine is easiest recognized when it is more or less changed to a reddish micaceous mineral. The magnetite is not conspicuous in the hand specimen, but is easily attracted from the powder by a magnet."

#### R. PUMPELLY'S DESCRIPTION OF A TYPICAL OPHITE.†

Dr. Pumpelly describes a typical ophite, the "Greenstone," as follows: "The rock, commonly known in the copper district as 'the Greenstone,' is the best type of this subdivision. Forming a bed 400-500 feet thick, dipping northerly, its outcrop consists of a continuous series of ridges and nearly vertical escarpments, often several hundred feet high. These extend from the Allouez mine to Point Keweenaw and form both the most salient topographical feature of the peninsula and a well-defined horizon to which the geologists and the miner refer their measurements. The rock has suffered only to the extent of a partial alteration of one of its constituents—the olivine.

"It is dark-green, greenish-black, finely crystalline, very compact, hard, and brittle, and breaks with an uneven to semi-conchoidal fracture. Porphyritic crystals, apparently of orthoclase, from 1-3 inch in length down, occur here and there—one or two on the surface of a specimen. They are generally single individuals; but sometimes twinned after the Carlsbad law, as is shown by the oppositely inclined basal cleavage. The powder of the rock yields to the magnet a beard of magnetite. The specific gravity is 2.92-2.95. It is an important characteristic of this rock, that its freshly fractured surface is mainly occupied by spots 1-3 to 3-4 inch in diameter, each of which reflects the light with a satin-like sheen. The reflection is not carried to the

\*Vol. VI, Part 1, Pl. 6, Fig. 3 and p. 167. I think the feldspar crystallizes better in the presence of steam, and that these doleritic streaks are where the lava had more water vapor.

†Proc. Amer. Acad. Arts and Sci., Vol. XIII, 1878, p. 260.

eye from all the spots at once; it is generally necessary to change the position of the specimen many times to observe the different reflections. Aside from this sheen, there is nothing, either in difference of color or texture, visible to the naked eye, to betray the presence of these spots, which might be called lustre-mottlings.

"To the naked eye, this phenomenon suggests, at once, interrupted cleavage of large individuals of one of the constituents, as the cause; but under a strong hand-glass, these reflecting surfaces show the same granular texture and character as the rest of the rock; and it is only when examined under the microscope, with an objective of the low power and in polarized light, that the appearance to the unaided eye is corroborated. We here find the cause in the fact that each spot is the cross-fracture or cleavage of a crystal of pyroxene, which in crystalizing has enclosed hundreds of feldspar crystals.

"The weathered surface is rusty gray, scarcely 1-50 inch thick; but it is covered with knobs which are due to the more rapid destruction of the materials between the pyroxene individuals.

"Examining thin sections under the microscope, we find the constituents to be plagioclase, pyroxene, olivine, and its alteration product, as well as magnetite, and an unindividualized substance, both fresh and altered, occupying interstices.

"In thin sections, the plagioclase is seen to exist in very sharply defined and fresh, thin, tabular crystals .001 to .002 inch thick and .01 inch, and less, long. It contains scattering interpositions of an opaque black substance, and minute brown particles, which may be, or have been, glass.

"The crystals of plagioclase have predetermined the contours of all the other constituents, except the olivine, which crystallized first.

"The predominating feldspar is anorthite, as determined by the angle between the principal sections in adjoining bands in the zone 0.1.i. Scattering large crystals, which happen in the sections to be cut parallel to i.i, have their principal sections at an angle of  $23^{\circ}$  with the edge 0.ii, which would indicate albite or labradorite.

"The augite is very fresh and transparent, almost colorless in the thin section, but with a tendency to purple-gray. An imperfect cleavage is indicated by somewhat irregular parallel fractures. It fills the interstices between the closely packed individuals of feldspar in such a manner that a single pyroxenic crystal encloses many hundreds of these, while its crystalline integrity is shown by the uniform color in polarized light, and by the arrangement of the cleavage cracks throughout the area of the augite individual.

"It is a remarkable fact that, while these large individuals of pyroxene contain thousands of feldspar crystals, they enclose only very few of

olivine or of magnetite. These minerals, together with the unindividualized substances, are crowded into the spaces between the pyroxenes. In this intermediate space, which surrounds the pyroxene individuals with a continuous network, we find also a few small pyroxenes, just as isolated grains of olivine occur in the pyroxene areas.

"A careful examination of this occurrence will, I think, convince the observer that at the time the pyroxene crystallized both the olivine and the feldspar crystals, and apparently the magnetite, were already individualized; for, where we find any of these in contact with the pyroxene, we see that the latter has adapted itself to the already defined contours of the others. While the pyroxene enclosed the feldspar crystals with ease, it crowded the other constituents almost wholly into the surrounding spaces; a process which was facilitated by the presence of the then fluid, unindividualized substance.

"The pyroxene contains also brown interpositions similar to those in the feldspar, and some opacite. Where it occurs with olivine it often surrounds the grains of this mineral.

"The magnetite bodies are of irregular shape, moulding themselves sharply around the contours of the feldspar and olivine. Their sharply defined outlines are black and fresh.

"The olivine is abundant in integral and aggregated grains, and, very rarely, in crystals with recognizable though rounded contours. The individuals are .0008 to .005 inch in diameter, and are readily distinguishable from the augite, between crossed nicols, by the difference of colors, and in the crystals, by the parallelism of the principal section with the longer sides. Where pains have been taken to give a tolerably good polish to the surfaces of the thin section, the characteristic finely pitted surface of the olivine distinguishes it, even in ordinary light, from the augite, which takes a more perfect surface.

"There are few grains of olivine in this rock that are not more or less altered to a very pale green substance, sometimes tinged with brown. Under a high power, the olivine is seen to be traversed by intercommunicating canals .0002 to .00005 inch thick, filled with clear faint yellowish green to greenish-blue substance. From the sides of these channels, jagged points of the same substance penetrate the fresh olivine. In this manner larger or smaller parts of the grains have been changed to a feebly double-refracting substance which gives an aggregate polarization due to the arrangement of the minute individuals of the alteration product, which are sometimes felted, at others, parallel fibrous. This product is dichroitic; the pale green when the fibrous structure is parallel to the shorter diagonal of the polarizer, and pale orange when parallel to the longer diagonal. On the uncovered sections, this alteration product was found to be very soft under the needle

“Apparently, not more than twenty to thirty per cent of the olivine is altered, which is very remarkable in a rock of such great age, considering the fact, which is emphasized by Zirkel,\* that the olivine is subject to complete alteration, even when its neighbors remain wholly intact.

“Where the interstices between the constituent crystalline minerals are not occupied by augite, they are filled with a transparent substance, in places colorless, in others of faintest green, almost colorless, only just distinguishable from the colorless feldspar in ordinary transmitted light. It often penetrates the feldspar crystals in cross fractures. Between crossed nicols it is black, sprinkled with minute blue-gray clouds—an aggregate polarization due, probably, to either an exceedingly minute radiating fibrous, or a granular, structure. Under a 1-16 inch objective (Hartnack’s No. 10), portions of the black seem to remain dark on revolving between crossed nicols. The substance is at the most only very feebly double refracting. Unfortunately I was able to find with a low power, and to try with the needle on an uncovered section, only those portions which were faintly green, and these were soft. Still, I am forced to believe that we have here to do with remnants of glass base, which is altered in the faint green portions to a chloritic or serpentine substance. Its whole mode of occurrence in this very fresh rock shows conclusively that it is not an alteration product of any of the constituent crystalline minerals.

“The relative ages of the constituents of this rock appear to be well defined as follows:

(1)	Original Magma.				
(II) 1. Olivine.	2. Plagioclase. (Anorthite.)	3. Magnetite.	4. Augite.	5. Residuary Magma.	
1 (a) Dichroitic alter. product.				5 (a) Alteration product.	

“The residuary magma (5) must have been the last to solidify; to its presence was due the internal mobility of the mass, which rendered it possible for the augite to crystallize in larger individuals, and, in doing so, to crowd from its centers the olivine and magnetite individuals.

“This residuary base, probably, differs in chemical constitution from the original magma, since it is only the residue of this after the removal of the ingredients forming the crystalline constituents.”

\*Mikrosc. Besch. d. Mineralien u. Gesteine, p. 217.

## R. PUMPELLY'S DESCRIPTION OF THE CONGLOMERATES.

R. Pumpelly thus describes\* the conglomerates: "The conglomerates of Portage Lake differ from each other but little, if at all, in lithological characteristics. The pebbles vary from the size of a pea to one foot or more in diameter, being coarser in some beds than in others. The different beds vary in thickness from mere seams to several hundred feet, and the same bed often varies greatly in width.

"The pebbles, in most of the beds on Portage Lake, consist almost exclusively of varieties of non-quartziferous felsitic porphyry. Two kinds predominate. One of these has a chocolate-brown to liver-brown subcrystalline to compact almost vitreous matrix containing very scattered minute crystals of triclinic feldspar of the same color as the base. The other and rarer variety, also non-quartziferous, has a chocolate-brown, compact to minutely crystalline matrix in which lie crystals 1-8 to 1-2 inch long, of a flesh-colored triclinic feldspar.

"In some beds there appear pebbles of a flesh-red rock, composed almost entirely of granular feldspar, containing small specks of a black undetermined mineral. In some instances the feldspar is wholly triclinic, in others the twin-striation is frequently absent. This variety of pebble is altogether absent in some beds, at least where they are opened, while in others they predominate, as in the Albany and Boston Conglomerate. Pebbles of compact melaphyre and of melaphyre amygdaloid also occur, but are quite subordinate in number to those already enumerated.

"The normal form of cement is a fine-grained sandstone, composed apparently of the same material as the pebbles. Often the cement is very subordinate in volume, the pebbles touching each other. Frequently, however, the reverse is the case, and often, the sandstone forms layers from less than an inch to many feet in thickness.

"The original character of the cement is often entirely lost; the interstices between the pebbles are sometimes, though rarely, empty. In places the sand is associated with oxide of iron, chlorite, a white talc-like mineral, and carbonate of lime, or it is entirely replaced by calcite, chlorite, epidote or even native copper.

"It is a remarkable fact that while all the conglomerate beds near Portage Lake are free from pebbles of quartz-porphyry, those in the neighborhood of Calumet are characterized by pebbles rich in grains of quartz. This abrupt change takes place about six miles northeast from the lake."

\*Michigan Geological Survey, Vol. I, Part II, pp. 16-17.



## A. C. LANE ON DECOMPOSITION OF THE KEWEENAWAN ROCKS.

Dr. A. C. Lane has summarized\* the changes as follows:

"I. 1. Primary reactions, glass decomposes, chloritic filling to cavities, ferric minerals (olivine, etc.) attacked. Chalcedony, agate, quartz, delessite and serpentine, and epidote formed; laumontite, thomsonite, and chlorastrolite in amygdules?, iron bearing red calcite, orthoclase? and ankerite? Some of these reactions may not be all primary.

II. Secondary reactions.

"2. Prehnite, other kinds of chlorite, also epidote and quartz formed; lime-bearing minerals dominant.

"3. Iceland spar (calcite) and copper formed.

"4. Selenite, barite, datolite, orthoclase, natrolite, apophyllite, analcite, and the sodium bearing minerals, fluccan.

"In the four groups above it must not be understood that the order is absolute but that on the whole the copper is most intimately associated with calcite, but at times occurs sprinkled through the prehnite and epidote as the contemporary.

"It is, however, true that the minerals of the last group are rarely if ever formed before those of the earlier ones and the first group are often replaced by the later ones. Chloritic replacements are common.

"It is understood of course that primary orthoclase of the original felsites may be and often is replaced by the others, and calcite occurs of all ages. An older calcite is often bright red.

"These studies are adapted from Pumpelly's thorough studies of the order of crystallization, Volume I, Part II, p. 32 of these reports, with additions."

\*Pub. 6, Mich. Geol. Sur., p. 858.

## CHAPTER IV.

### NATURE OF THE COPPER DEPOSITS.

#### MODE OF OCCURRENCE OF THE COPPER.

*The Copper Minerals.*—Practically all of the copper mined occurs as the native metal. A very minor production is made from other copper minerals, chiefly arsenides. The deposits are remarkable for their very meagre content of sulphides. Chalcocite is the most common sulphide, but it is seldom found in large quantity. Oxide, carbonate and silicate minerals containing copper have been found frequently, but not in economic amounts.

*The native copper* occurs chiefly in bedded deposits. It has filled cavities in and replaced mineral and rock constituents of conglomerates and amygdaloids. If we except the fissure veins, the richest lode is a conglomerate; but all the other lodes now being worked are amygdaloids. Large amounts of native copper have also been mined from fissure veins which cut across the formation, and from epidotic veins or beds which lie nearly parallel with the formation. One deposit which promises to be profitable is a sandstone containing native copper and chalcocite. Native copper has also been found in a much fissured and altered mass of felsite.

*The bedded deposits* are long and continue to great depths. The most important ones are being worked for a distance of two to five miles along the strike. Two of the lodes are still being worked at over a mile down on the slope of the beds, and it is probable that others will be worked at a like depth. Most of the lodes average at least eight, and some over twenty-five feet in thickness.

*Distribution of the native copper.*—The copper is by no means evenly distributed throughout the lodes. Very large stretches are mined out in continuous stopes, but the regularity indicated by the stope maps gives an erroneous impression of the occurrence of the metal. Large quantities of barren rock are broken with the ore, and the copper-bearing portion has a content varying from a few pounds to several hundred pounds per ton. The rich ore forms a comparatively small portion of the output. The amount of waste rock included with the ore shipped varies not only with the deposits, but also according to

the amount of hand sorting that is done in the mine. In some mines the ore is rather carefully picked and much of the rock broken is left underground. In other cases nearly all becomes mixed with the ore. It should be evident from these remarks that the proper interpretation of reports on yield per ton of different lodes or parts of the same lode requires a knowledge of the method of mining and handling the ore. Further information is to be found on the stope maps which show ground supposed to be barren or very low grade. It is common practice to record daily the character of ground opened in drifts, but most of the mine maps fail to show in any other way the grade of ore mined from individual stopes. The output from most shafts shows considerable uniformity in grade of ore produced from day to day, but this is largely due to the common practice of mining simultaneously in many widely separated stopes.

*Productive portions of beds.*—The irregular distribution of the metal is frequently commented on by the miners. Assays are seldom necessary and are not very satisfactory. Where there is any considerable quantity of copper, the mineral is readily detected by the naked eye or by feeling the rough jagged projections, and rich and poor ground are thus readily distinguished. It is known that the ore-bearing portions of a bed are of all shapes and sizes. It is common experience in a single stope to have a whole face in good ore followed for a few cuts by practically barren ground and then by good ore again. Within the limits of a stope the ore occurs in several bodies which are perhaps best referred to as *patches*. Sometimes the patches are larger and a whole stope may then be continuously in ore. These patches, small and large, form parts of still larger areas of the lode which are referred to as the *productive areas* and which are of very great size.

*Shoots.*—While the ore does not occur in shoots, in the sense in which this term is most commonly used, the productive areas bear a somewhat similar relation to the bed of which they are a part, as do shoots to veins. The difference is, at least partly, one of magnitude. The great size of the productive areas is a feature which distinguishes these from most other ore deposits and the use here of the term oreshoot is thus made after some hesitation and because there is no similar term available for deposits of such magnitude.

Some of these so-called shoots show a marked pitch along the strike. The Calumet shoot pitches almost due north and others in Houghton County pitch in a northerly direction. The pitch of the ore bodies at the Quincy mine is shown by the old stope plan, Fig. 21. At Victoria mine, the pitch is toward the west. No very accurate record is kept of the output of individual stopes. Hence there are no figures available from which to construct diagrams showing how the copper was dis-

tributed in the ore mined. In some mines it is the practice to make daily notes on the character of new openings. This is commonly done by the captain or shift boss who notes simply whether the showing is good, fair or poor. From these notes maps have been constructed showing approximately the distribution of copper for large areas of a lode. These however are not available for publication. Not infrequently the necessary information has never been recorded, but entrusted to the captain's memory and ultimately lost entirely. Some idea of the distribution of the metal may be obtained from the description of individual lodes given in this report.

*Change in value with depth.*—The deposits show no very regular change in copper contents with depth. The deepest workings in the district are in comparatively lean ore. The best ore in the Calumet conglomerate was taken at depths from surface which increased as the workings were extended to the north. The statements of several who have commented on the change with depth agree to the extent that below 2,000 feet the ore does not average as rich as above 2,000 feet. It is probable however that the average for depths of 1,000 to 2,000 feet is above that of the portion above 1,000 feet. Mr. Jas. MacNaughton, general manager of the Calumet and Hecla Mining Co. states that "the copper contents lessen with depth and the falling off in richness begins to be noticed at 2,000 feet." This statement is a general one for large areas of a lode. It should not be interpreted to mean that there is a gradual falling off in values. The lodes are patchy.

#### CONGLOMERATE LODES.

*Characteristics of the Conglomerate Lodes.*—The conglomerate lodes are portions of sedimentary beds which are interstratified with the volcanic rocks. They are commonly reddish rocks with very numerous large pebbles. The pebbles are mostly quartz-porphry and felsite, but there are occasional pebbles of many different types of trap and amygdaloid. The cement is a rather coarse sand made up of small rock grains and a few minerals of which the most common are calcite, quartz, native copper, and magnetite, hematite (var. martite) or other oxide. Epidote and chlorite are of frequent occurrence as constituents of the sand and as alteration products of the pebbles. In places these sedimentary beds contain few or no large pebbles, but in the copper-bearing zone such sandstone portions are usually subordinate to the coarse conglomeratic phase. At the Franklin Jr. mine, the lower part of the Allouez conglomerate bed is a sandstone.

Considering their character, the conglomerate beds are remarkably persistent, for it might be expected that they would vary much more

in thickness than they do and frequently pinch out. On the lode which has been most extensively worked, the Calumet lode, variations in thickness from a few feet up to 40 feet have been found, but as the workings extend two miles along the strike and over a mile down on the dip, it is remarkable that the thin bed of coarse conglomerate was spread out so evenly. That some other conglomerate beds in the district are much less regular in thickness has been shown by Dr. Hubbard.\*

*Copper is in both pebbles and matrix.*—In the conglomerate lodes the copper occurs chiefly in the matrix, where it has apparently filled spaces between and also replaced grains of mineral and rock. While part of it occurs in fine particles which may have been deposited between the sand grains, much of it is in particles of size and shape not in accord with such origin and it seems likely that most of the copper has replaced other constituents. Native copper also occurs in the pebbles and frequently these are quite heavy with the metal. Examination of these pebbles shows conclusively that the deposition of the copper has been made at the expense of the rock. It does not occur simply as a filling in fractures in the pebbles, but has rather the character of a pseudomorph after the pebble. Frequently the copper is in the form of a shell, but in other cases it occurs in irregular masses throughout the pebble, sometimes almost completely replacing it. At some rockhouses very large numbers of these heavy pebbles have been picked out from the ore and sent directly to the smelter. The present workings do not afford so many as were encountered a few years ago.

*Copper is in small particles.*—The copper in conglomerate lodes is commonly in smaller particles than that in the amygdaloids. Large masses have occasionally been found, but they are comparatively rare. Small masses or "barrel work" are also infrequently met with. With the exception of the copper pebbles, practically all the conglomerate ore is stamped and concentrated before smelting, while a very considerable portion of the copper from some amygdaloid lodes occurs in large and small masses which are sent directly to the smelter.

The replacement of pebbles by copper has been described by Dr. Raphael Pumpelly and Dr. A. C. Lane, and will be referred to later in this report in the discussion of origin of the ore.

#### AMYGDALOID LODES.

*Characteristics of amygdaloid lodes.*—The term amygdaloid lode is applied to those deposits which occur in much altered portions of the

\*L. L. Hubbard, Geol. Sur. Mich., Vol. VI.

volcanic beds. Usually they are the upper part of the bed and decidedly amygdaloidal in character. Some, however, are not markedly amygdaloidal, and a large part of the ore in some mines occurs as replacement deposits and fracture fillings in fissured traps.

As a rule the rock carrying high values in copper is largely made up of secondary minerals, and the metal is usually enclosed in masses of these, especially in calcite, epidote, prehnite, chlorite and quartz. Copper occurs as a filling in amygdaloidal cavities, but it is by no means confined to them. In some lodes there is considerable copper with calcite, prehnite and quartz in minor fissures, but other lodes show little ore of this character. In some cases native copper occurs in a network of seams. These seamed masses show characteristics of mineralized shattered zones, but as the mineralization is confined largely to single beds the deposits are tabular masses similar in shape to the beds which are not so much fractured.

The amygdaloid lodes seldom occur singly, the chief producing lodes being closely accompanied by others carrying a subordinate amount of copper. In some cases, and this is notably so of the Kearsarge amygdaloid, the quantity of ore mined from the "east" and "west" lodes is almost negligible, but in other cases, of which the Pewabic is a notable example, there are two or three lodes of importance. The main lode at one shaft at the Quincy mine is not the lode which was regarded as the main lode at another shaft.

The Pewabic is thus a series of lodes which vary in relative importance from place to place. They are commonly spaced a short distance apart and occasionally come together, then often forming unusually large bodies of good ore. A somewhat similar feature is characteristic of the several lodes at the Mass Mine. On the Osceola amygdaloid the ore occurs partly in a fairly regular hanging portion and partly in a less regular but much thicker foot portion. At the Superior Mine there has been opened up a rich lode which lies a short and variable distance above the Superior lode. At the Isle Royale Mine, there are two somewhat similar lodes—the Isle Royale and the Grand Portage—spaced a short distance apart. At the Copper Range mines crosscuts into foot and hanging from the Baltic lode often disclose additional ore.

*Hard portions.*—Throughout the amygdaloid lodes there occur irregular masses, frequently somewhat lenticular in shape, that are much harder than the surrounding rock. Such masses are commonly greenish in color and consist largely of a dense aggregate of epidote and other green minerals with quartz. The frequent occurrence of this material is called to the attention of the miners by the comparatively great difficulty encountered in drilling it.

*Soft portions.*—Occasionally also there occur very soft portions, in

which much of the rock is friable and readily breaks away from irregularly branching copper masses which it contains. It has been noticed in some mines that these soft streaks commonly run across the lode, while the hard epidotic masses extend in the direction of the lode. There is often much copper in the epidotic rock and many masses occur in it.

*Wet and dry portions.*—It is often noticed that rich parts of the lode are wetter than the dry and in some mines the encountering of a little water in the openings is considered a sign of better ore ahead.

*Crushed portions.*—It is often found in following the lodes, that portions which are fractured and crushed very extensively are comparatively poor in copper contents. Dr. Lane says\* regarding this phenomenon: "So far as my experience goes, where there is a great deal of disturbance and the rock is thoroughly decomposed, it is not likely to contain copper. The copper seems to be driven from it into a zone between the thoroughly disturbed and the less disturbed rock."

*Shear zones.*—As Dr. Hubbard has pointed out, some of the amygdaloid beds are seats of shear zones, the copper and other secondary minerals occur in cavities caused primarily by shearing. He says:†

"Observation has already shown us that the copper in the amygdaloids is generally found not in the amygdaloidal cavities, but in brecciated material—in fissures. The thick footwall bed rendered possible a widespread and bubble-studded capping, in other words, a marked and extensive plane of weakness which would be particularly susceptible to shearing. The more circumscribed the amygdaloidal capping, by comparison with the more compact rocks in the extension of its plane, the less it would be subject to shearing, and consequently the less it would offer cavities of mechanical origin for the deposition of secondary minerals. At the Champion Mine, I remember to have seen in six years only one piece of rock that contained shot copper. In the Winona Mine a similar condition exists. Moreover in the latter mine a well defined slip marks the course of the lode on the hanging-wall side, and other evidences of shearing are seen in the adjacent rock material. At the Ojibway near the shaft that has uncovered the more copper, a fissure vein in the hanging of the east lode is in evidence from near the surface to the bottom of the mine. I say fissure vein because I believe that specimens of crystallized copper occur more often in what we are accustomed to call fissure veins than in accidental cavities of more irregular occurrence."

He states further‡ "We may expect to find shearing either (1) limited approximately by the area of any one of these beds; (2) extending

\*L. S. M. I., 1912, p. 135-136.

†L. S. M. I., 1912, p. 231.

‡Loc. Cit. page 230.

into or through an adjoining trap bed; (3) deflected into a transverse fault, or from the latter (4) transmitted into another amygdaloid.

"Of the first of these cases, we can probably collect little material evidence in this area, because we do not often mine in the traps beyond the limits of the copper. As to the second, I have sometimes thought that the Mabbs vein may possibly be the extension of the Baltic-Superior shear zone system, through the more compact trap; that the temporary disappearance of the Baltic zone of enrichment north of the Baltic Mine is due to the cross fissuring and disturbance in Section 16; and that the Arcadian-Isle Royale and Grand Portage lodes come under the fourth class of a shear transmitted from one plane of weakness to another."

*Spliced structure.*—Dr. Hubbard describes the development of a spliced structure in a bed and compares it with similar structure found in veins. He says:\*

"The spliced structure above referred to was applied by Pumpelly to the ordinary fissure vein. The causes that produced it must be the same or closely allied to those that bring about shearing in the tilted beds of volcanic origin. In our amygdaloids we see these on a comparatively small scale. Near the extremity of Keweenaw Point 'accomodation' appears to have been made so far as evidence is at hand, largely in the cracks that run across the formation, some of them copper-bearing, and in the Ontonagon district the drag of the overlying beds has resulted in at least two cases in fissure veins that strike nearly parallel with, but dip more steeply than, the beds of the series. It is largely between these two areas that our productive bedded deposits have been found. May they or some of them not be due to mechanical movements very similar to those that produced the so-called fissure deposits at each end of the district."

*The copper bearing beds are thick.*—The amygdaloid lodes now being worked are parts of thick beds. According to Dr. Hubbard† the footwall trap at Winona Mine is 40 to 50 feet thick; at the Baltic and Champion from 100 to 150 feet thick for a length of four miles; and at Ojibway and Mohawk it (Kearsarge Foot) will probably average more than 100 feet and maintains a much greater thickness for several miles. It has been pointed out by Dr. Hubbard that the upper part of thick beds formed more or less continuous horizons of weakness through which shearing might easily take place, more easily than in beds of smaller area.

Dr. A. C. Lane remarks‡ that the most favorable place for copper is

\*Loc. Cit., p. 234.

†L. S. M. I., p. 230, 1912. "In the Lake Superior area what influence, if any, did the thickness and contour of foot-wall beds have upon the subsequent disposition and distribution of copper in overlying beds."

‡L. S. M. I., 1912, p. 128. Unexplored parts of the copper Range of Keweenaw Point.



"A belt near a heavy impervious belt, and in a somewhat pervious one, in which a certain amount of shattering has taken place." He elsewhere\* calls attention to the fact that copper is commonly found under heavy impervious beds.

*Dr. R. D. Irving*, in Mono. V, U. S. G. S. says of the amygdaloids, "The copper in these deposits is not restricted to that portion of the bed which was originally vesicular, but runs from it downward irregularly into the originally compact portions, following always a great alteration of the rock. The copper, however, tends always to be very irregular in distribution, and, even in the longest worked and most reliable amygdaloids, has frequently to be searched for through many feet of barren rock. In this search the diamond drill is now extensively used, the miners being guided in its use by the occurrence of seams of calcite and epidote, and other alteration forms, which, when followed up with the drill, are often found to lead to pockets containing much copper.

"In one class of amygdaloids, those of the ashbed-type—which I agree with Wadsworth in regarding as merely very highly scoriaceous and open lava flows, into whose interstices the intermingled detrital material has subsequently been washed—the distribution of the copper is sometimes more uniform than in the ordinary cupriferous amygdaloids, so that the whole of the bed may be broken down and taken to the stamps, as is done for instance at the Atlantic mine."

#### SANDSTONE LODES.

*Nonesuch and White Pine.*—In some deposits in the Porcupine Mountain District, Ontonagon County, copper occurs in sediments of the upper Keweenawan. At the Nonesuch and White-Pine mines the cupriferous beds are gray sandstones which are in places conglomeratic. Copper occurs as the native metal and as a sulphide, chalcocite, distributed in the form of small grains and flakes. Some of the copper is in mere films which are readily carried away by water and hence not easily saved, but much of it is in grains that can be concentrated economically. The sandstones are largely made up of quartz grains with some darker colored rock particles and minerals. Among these grains the copper occurs partly in forms which suggest simple filling of spaces, but partly at least is probably a replacement. According to some authorities† copper frequently occurs as a coating on grain of magnetite.

\*Pub. 6. Michigan Geological Survey, 1912, p. 44.

†Steidtmann. U. S. G. S. Monograph No. 52, Geology of Lake Superior District.

Dr. Irving notes\* that at the Nonesuch Mine most of the copper is clustered around magnetite particles.

#### EPIDOTIC BEDS.

*Ontonagon "veins."*—Epidotic beds, yellowish green in color, and composed largely of epidote and quartz, are of common occurrence, and several contain native copper. Such deposits are not commonly very productive; but in Ontonagon County a very profitable mine, the Minesota, had most of its copper in such an ore body.

The beds, or veins as they are sometimes called, strike with the bedded volcanic rocks, but dip somewhat more steeply and are hence not confined to one horizon. Many exceptionally large masses were found in the Minesota deposit.

*Irregular distribution of the copper.*—Chas. E. Wright describes the irregular distribution of the copper in these deposits. He says:†

"In Ontonagon County the copper occurs in veins and in belts, which run with the formation. The copper-bearing veins, while conforming in direction with the strike of the inclosing rock, frequently dip at a greater angle, but always in the same direction. The beds which have been mined for copper are frequently distinguished by their irregularity, rendering it extremely difficult or impossible to define them. The product, which has been mainly in the form of masses, is in some portions of the range found scattered in the trap rock in a manner that sets at defiance any method of determining their location other than mere chance; blind, persistent work may lead to the discovery of an isolated mass or of a collection or a succession of masses, but it is frequently blind luck, and not the result of following any well defined clues."

*Irving on Ontonagon Veins.*—R. D. Irving in Mono. V, U. S. G. S. says of the bedded veins of Ontonagon County: "The copper deposits of the Ontonagon region have not had the study given them that has of late years been devoted to those of the Keweenaw Point and Portage Lake districts; so that it is not possible to be quite so positive in our statements in regard to them. The copper of this region never occurs in transverse fissures, but either lies in irregular accumulations—often solid masses many tons in weight—associated with much epidote and calcite, distributed along the course of diabase beds, or else occurs with more persistent and vein-like aggregations of epidote and calcite. The latter coincide always with the bearing of the formation, and commonly also with its dip, but in some cases, as for instance in the once famous Minesota mine, dip at a higher angle than that

\*Vol. V, U. S. G. S. Copper Bearing Rocks of Lake Superior, R. D. Irving, 1883, p. 221.

†Report of Com. of Min. Statistics, Michigan, 1880, p. 68.

of the formation, which they consequently slowly traverse in depth. According to Foster and Whitney, deposits like that of the Minesota mine show another indication of a vein-like character in the shape of slickensided and generally sharply defined walls. The 'vein' at the National mine is also peculiar in lying at the base of one of the great lava flows, and immediately above a conglomerate bed, while coinciding with them in both bearing and dip.

"It is evident, even with our present knowledge of the deposits of the Ontonagon district, that their history has been essentially the same as that of the Portage Lake deposits. In the case of that copper which occurs irregularly distributed, along with epidote and calcite, throughout certain of the trappean beds, the process of replacement has gone on irregularly, because of some irregularity of texture in the original rock. Deposits like that of the Minesota mine may have resulted from the deflection of the altering waters along the course of a pre-existing but not open fissure; the 'vein' being in this case, as before, a replacement, at least in large measure, of original rock substance."

#### CUPRIFEROUS FELSITE.

*Indiana deposit.*—Native copper and some malachite and chrysocolla have been found in recent years in masses of felsite at the Indiana and adjoining properties in Ontonagon County. While no deposits of this type have yet been extensively opened up, the management of the Indiana Copper Company considered that the showings obtained in drill cores are promising and a shaft has been sunk to permit of the testing of such deposits at a depth of over 1,400 feet.

The copper so far obtained occurs in portions of the felsite that are much altered and crushed and is usually accompanied by secondary quartz, calcite and epidote. In one case the copper occurs chiefly at the bottom of a mass of felsite, but in other cases it is well within the felsites traversed by the drills. The shape of these rock masses and their relation to the amygdaloids and sedimentary beds are as yet unknown. It is probable that the felsite occurs as irregular masses intruding the amygdaloids. Concerning the extent and shape of the copper deposits in the felsite there is as yet very little knowledge. Some of the information thus far obtained will be given in describing the Indiana deposit.

#### FISSURE VEINS.

*Occurrence of copper in veins.*—In fissure veins the copper occurs in masses, very irregularly distributed. The veins which have been extensively worked are all in Keweenaw County and most of them at nearly the same horizon—just below the thick bed known as "the

Greenstone." They cut across the amygdaloid and trap beds and commonly are more productive and wider in the amygdaloids. In the dense traps and in sandstones the veins contain but little copper. At present no fissure vein deposits are being worked independently but considerable quantities of ore are taken from veins traversing the Kearsarge lode at the Ahmeek and Mohawk mines. Years ago large production was made from veins at the Central and Cliff mines.

In the deposits mined at the Cliff, Central and several other properties, the copper occurred almost entirely as the native metal. At the Mohawk mine similar deposits yield arsenides which carry some cobalt and nickel in addition to copper. At the Ahmeek mine there is a very rich vein carrying native copper in a calcite gangue, and some mohawkite veins which have quartz as the chief gangue mineral.

*Central and Cliff Veins.*—According to those who examined these deposits when they were being worked, the copper commonly occurs with epidote, prehnite and chlorite. Calcite is abundant in most of the veins, but is stated to be not specially characteristic as there are many barren calcite veins. Numerous masses of country rock are enclosed in the vein matter. The veins are nearly vertical and the mine maps show that the ore bodies pitched with the dip of the beds traversed.

*Ahmeek Vein.*—The Ahmeek fissure vein crosses the Kearsarge amygdaloid close to No. 2 shaft and has therefore been frequently cut in drifting on the Kearsarge lode. It shows good ore on several of the upper levels, but has not been extensively opened up there. At the tenth level there is a drift on the vein for 245 feet into the hanging which has opened up remarkably rich ore. The copper occurs in thick slabs in masses of several tons. A short drift at the thirteenth level uncovered a slab twenty-eight feet long which was with difficulty broken into several pieces each weighing a few tons.

The vein varies in thickness from a mere ribbon to three feet and in places breaks into two parts separated by rock. It strikes across the Kearsarge lode and dips at about 70° northeast.

*Production of fissure veins.*—As compared with the amygdaloid and conglomerate lodes, the output from fissure veins has been very small and with the one conspicuous exception, the Ahmeek, it is at present almost negligible. Special interest is attached to them however, by the fact that the richest part of such veins is commonly found to be at the intersection with one of the cupriferous beds and hence they are encountered while mining the beds.

The most productive of the known vein deposits were worked out many years ago at the Cliff and Central mines. I can give no de-

scription of these deposits from personal observation, but may do some service by quoting from works not now readily available.

*C. E. Wright's description of Central Mine Vein.*—In the report of the first Commissioner of Mineral Statistics\* Mr. Chas. E. Wright says of the Central Mine deposits:

“The vein, which has nearly a north and south course, dips to the east. The principal product is mass copper of 65% purity; the deposits of this metal are found in talcspars, sugar spar, laumontite, chlorite and other minerals, often occurring in the form of beautiful crystals. The masses are often enormous, irregular slabs—isolated bodies of copper—and weigh in gross from 400 to 800 tons. They are mined by working on each side and removing the vein rock, and are blasted down so as to expose one face, by sand blasts in which several kegs of powder are used. They are cut, by means of chisels, into convenient blocks for handling, of from four to eight tons each. Some of these blocks are of great purity; when hoisted from the mine they are sent to the smelting works without further dressing.”

The copper in the Ahmeek vein is also exposed by drifting in the rock on either side; but it is broken into pieces by heavy charges of 90% nitroglycerin and not cut, if cutting can be avoided.

*R. D. Irving's description of fissure veins.*—R. D. Irving says† of the productive veins.

“The transverse veins have been mined for copper on Keweenaw Point only, where they are found varying in width from mere seams to ten and even twenty and thirty feet. For the most part, however, they do not exceed one to three feet in width, the expanded portions being met where they traverse the amygdaloidal or otherwise open textured portions of the flows. The same veins which, in the amygdaloid and looser textured diabases, are expanded and often rich in copper, will, when in the more compact and massive beds, such as the well known Greenstone, contract to mere seams without metallic content; and the same is in large measure true of their intersections with the sandstone belts. The veins lie always very nearly at right angles to the trend of the beds which they traverse, standing always very near the perpendicular quartz, calcite and prehnite make up the common veinstone, but they are mingled with more or less of the wall rock of the vein, which frequently predominates greatly over any true veinstone. The veins are in fact for the most part not sharply defined from the surrounding rock, but consist in each case of a network of smaller seams traversing the shattered wall rock. Veins composed almost wholly of calcite are not unknown, but they are never productive

\*Lake Superior Copper Mining Industry, p. 178, 1877-78. Report Commissioner of Mineral Statistics State of Michigan, 1897.

†Copper-Bearing Rocks of Lake Superior, Mono. V., U. S. G. S., p. 423.

of copper. The copper in these veins occurs both in smaller fragments and minute particles intimately mixed with veinstone, and again in masses many tons in weight. The larger masses frequently are found to contain within them portions of the wall rock.

"Nearly all the productive mines based on these transverse veins are working directly beneath the Greenstone, the layer which is described in a previous chapter as constituting as prominent a feature in the geology and topography of Keweenaw Point. This position of the mines is one not due to the non-occurrence of copper elsewhere in the course of these veins, but results from the fact that further south they become buried beneath a heavy coating of drift, while to the northward they pinch out and become barren in the broad Greenstone belt.

"These veins, on account of their transverse position to the bedding of the formation, of their often slickensided walls, and from their carrying often a true veinstone, have commonly been regarded as 'true fissures.' That they are on the lines of pre-existing fissures or transverse cracks in the formation there can, I think, be no doubt, but they are not true fissure veins in the sense that the veinstone and metallic matter occupy, along with wall-rock fragments, original fissure space. I see in them simply the results of rock alteration entirely analagous to that which has brought about the deposition of copper and its associated veinstone minerals within the cupriferous amygdaloids. They are alteration zones which traverse, instead of following, the bedding, simply because the drainage of the altering waters has been given this direction by the pre-existing fissures. All of the phenomena of these veins coincide completely with the vein; the common occurrence of wall rock within the vein, or rather the embracing of the wall rock masses by the vein; the replacement of wall rock by copper masses; the occurrence of wall rock within these masses; the expansion of the veins and their greater richness where traversing the more readily alterable amygdaloids and looser textured diabases; their contraction and barrenness within the compact and less readily changeable Greenstone; and the coincidence of the paragenesis of the vein minerals with that of the cupriferous amygdaloids, are all facts better explicable on this theory than on any other."

*Wadsworth on veins.*—Dr. M. E. Wadsworth says\* of the vein deposits:

"In the veins the copper is found intimately mixed with the gangue, or in sheets or irregular masses. In sheet-form the copper extends downward or has its sides approximately parallel with the vein. Often the sheet is divided, and holds between its parts some of the gangue or melaphyre. It is also not uncommon to find, entirely enclosed in

\*Origin and Mode of Occurrence of the Lake Superior Copper Deposits. Trans. A. I. M. E., Vol. XXVII, 1897, p. 694.

the copper, masses of melaphyre, quartz, calcite or other vein-minerals. The melaphyres themselves are often impregnated with copper adjacent to the veins."

*C. E. Wright's description of Keweenaw County Veins.*—Chas. E. Wright describes\* the copper-bearing fissure veins of Keweenaw County in his 1882 report.

"The fissure veins in this portion of the range cross the formation, usually at an inclination approaching a right angle and dipping nearly or quite vertically; they vary in width from a few inches to several feet, sometimes, in very productive portions, widening out to even twelve feet or more. It is in these wide pockets that the greater portion of the copper is found; the extreme narrow portions of the vein serve only as leaders to guide in the work of excavating; the gangue of these veins is made up of quartz, calcite, prehnite, epidote, laumontite, datolite; quartz and calcareous spar are usually the predominating minerals. The rock in the richest metalliferous portions is a rather soft amygdaloid trap of a fine texture.

"These veins can be traced through the greenstone and have been found to be productive on both sides of it, but never in it.

"The product obtained from the veins is very largely in masses of native copper, or in pieces of a size termed barrel work. These veins sometimes contain more or less of the trap rock, in small pieces, to fragments of considerable size cemented together with the vein matter."

#### PARAGENESIS OF COPPER AND CALCITE.

R. Pumpelly has discussed<sup>1</sup> the relations of copper and calcite in several cases. He says:

"In many of the instances in which calcite crystals are found enclosing copper, it is difficult and often impossible to distinguish as to the relative ages of the two. But specimens in my collection offer conclusive proof that each of the following cases occurs:

"I. *The copper was present before the calcite began to form, and became enclosed in the growing crystal.* In this case the copper and its associated minerals generally form the basis on which the calcite rests, and the crystals of the latter exhibit entering faces wherever the surface of the crystal is in contact with the copper; it should seem to indicate an effort at those points to crystallize free from the foreign substance, by forming separate individuals. But on the finished crystal the traces of this tendency are visible, generally, only in the comparatively very small entering faces at the contact with the copper.

"In this way calcite crystals, formed in a cavernous mass of copper,

\*Rep. Com. Min. Stat. Mich., 1882, p. 55-56.

<sup>1</sup>Michigan Geological Survey, Vol. I, Part II, pp. 32-35.

are intersected internally by a perfect network of thin plates of the metal, and yet preserve their cleavage unaffected; but wherever the copper comes in contact with the surface of the crystal, the small entering faces are present.

II. *The crystal of calcite was partly formed, then became incrustated with copper, and was finished by a new growth of calcite over the metallic film.*<sup>2</sup>

"A most remarkable instance of this case is that of a crystal about two inches long—a steep scalenohedron—with a basal termination of about one square inch surface. At this stage of its growth it was covered, over nearly the whole surface, with a thin coating of copper. The basal termination on scalenohedrons of calcite is as rare on Lake Superior as elsewhere, and in the few instances where I have seen it, it lacks the polish which indicates perfect growth. The tendency to complete the point of the scalenohedron is well shown on this specimen; over the partially copper-coated basal plane there are scattered a large number of perfectly pointed scalenohedrons—two or three of these are 1-3 to 1-2 inch high—and others are scattered over the side-faces. All of these younger crystals are arranged in perfect uniformity with the plan of the underlying, older individual.

"Those portions of the surface on which the copper-coating is perfect have no younger calcite crystals; these occur where the metallic film is thinnest and more or less perforated.

"The copper is not confined absolutely to the surface of the crystal on which it lies; it penetrates to a slight distance along the cleavage-planes, and the result is an exceedingly delicate reticulation on its upper surface. The calcites which are planted on the copper contain brilliant particles of the metals swimming, if one may use the word, in the interior of the crystals; and these are so disposed as to lead to the idea that, throughout the growth of the younger crystals, they had to contend with the continued deposition of the metal. Thus one of the new scalenohedrons, after growing to the height of 1-4 inch, was, like the underlying one, also ended with a basal termination, on which again smaller new and well-pointed individuals were built up.

III. *The copper has entered the calcite crystal since its growth was finished.*

"A specimen, in my collection, illustrates this remarkably well. It is a cleavage-rhombhedron of opaque calcite, traversed by intersecting sheets of copper, which are wholly independent of the cleavage planes. On detaching the copper from the calcite, the surface of the latter appears rough; it is a fracture oblique to the cleavage, and the face of the fracture is formed by countless corners, or solid angles,

<sup>2</sup>Commenting on this Dr. L. L. Hubbard says: "In many cases the outer or later crystal is in twin position to the earlier. The earlier is generally milky and the later clear. These are distinctly two generations of calcite."



of minute cleavage-rhombohedral, as is fully proved by the reflection of the light. The copper-sheets, which are about 1-40 inch thick, reproduce this very completely.

"Another very remarkable specimen is from the cement of the Albany and Boston conglomerate. It is about one inch in diameter, and consists of opaque white calcite. The continuity of the cleavage shows it to be a single individual, though it passes on the edges without any sharp demarkation into the common cement of the conglomerate. This calcite is traversed by continuous sheets of copper 1-200 to 1-40 inch thick, which are perfectly straight. These sheets are parallel to several planes (nearly all of which are independent of the cleavage), and intersect each other. In each of the sets thus formed the sheets are perfectly parallel, and are separated by plates of calcite, which are, in places, as thin as the copper itself. Where three such sets intersect each other, the resulting solid appears composed of concentrically arranged laminae of copper and calcite. In some parts of the specimen, the copper predominated over the calcite. Wherever the faces of the copper laminae are exposed, they are marked with a delicate, reticulated tracery, indicating the lines of intersection of the sheet with the cleavage planes of the crystal. The cement in the vicinity of the calcite is impregnated with copper; in places it is almost wholly replaced by the metal in the fine granular condition called "brick copper," and into this the laminae of metal extend, without break, from the calcite. This specimen is really a pseudomorph of copper after calcite."

Dr. L. L. Hubbard has observed that in the trappy portion of the Kearsarge bed there are some feldspar crystals having copper along their cleavage planes.

#### SULPHIDE VEINS.

Sulphides are found in veins similar to those containing arsenides, but are of even less commercial importance. At some mines, notably those of the Copper Range Consolidated Company, very narrow veins are frequently encountered in working the amygdaloid lodes and the sulphide is thus mined with the native copper ore; but never in very large quantity. Many of the veins cut across the formation but others strike with it. Chalcocite ( $\text{Cu}_2\text{S}$ ) is the sulphide most frequently found. Covellite ( $\text{Cu S}$ ), Bornite ( $\text{Cu}_3\text{FeS}_4$ ) and chalcopyrite ( $\text{Cu FeS}_2$ ) also occur. Chalcopyrite is more common in the intrusive rocks of the Keweenaw than in the extrusives and is very rarely met with in the latter.

It was noted by Dr. L. L. Hubbard that some of the sulphide veins first observed seemed to pinch out at a comparatively short distance from the surface. However, deeper workings show quite numerous

sulphide veins. Many of these if traced can be found to pinch out upwards as well as downwards. They have apparently no dependence, as far as origin is concerned, on the present surface.

#### ARSENIDES AND SULPHIDES OF COPPER.

While seldom of economic importance, several arsenides of copper occur in veins traversing the amygdaloid lodes. The best known ones are keweenawite (Cu, Ni, Co), As; mohawkite (Cu, Ni, Co), As; whitneyite Cu, As; domeykite Cu, As; algodonite, Cu, As; and stibiodomeykite, a variety of domeykite. At the Champion mine a large quantity of algodonite was found.

*G. A. Koenig's Studies.*—These minerals were carefully studied and analyzed by Dr. George A. Koenig, who says\* regarding their occurrence:

“The knowledge of the existence of copper arsenides in the Keweenaw copper formation is nearly as old as the mining operations in this region themselves. In the matter of occurrence there are two points to be noted; (1) The arsenides are not found in the bedded deposits of native copper, but always in fissures, intersecting the beds. (2) These veins have thus far only been observed in the lower beds, near the foot of the formation to the southeast.\* Arsenic, however, is found in the smelted and refined copper of all the mines. This element is a minimal amount in the copper from the Great Conglomerate of the Calumet and Hecla mine and becomes a maximum in the copper from the amygdaloid beds of the lower measures, on which the Mohawk, Wolverine, Arcadian, Sheldon-Columbia, Isle Royale, Atlantic, Baltic, Champion, etc. are located. The Sheldon-Columbia location near the shore of Portage Lake in the village of Houghton was the first mine which furnished copper arsenides, notably domeykite. The larger parts of the specimens in collections come probably from this mine. Whitneyite was found in a quartz vein† in dark melaphyre, not far from the present Mohawk, but the existence of any copper rock was not suspected at that time at that point. Several masses of domeykite have been found in the drift on the Hancock shore of Portage Lake, very much decomposed, cuprite and arsenates being the chief products. In the spring of 1898, the opening of a new street in East Houghton on the old Sheldon-Columbia location, disclosed a quartz vein containing some foliated domeykite. Many good specimens were gathered and have come into collections. A similar vein has been known for years on the old Huron location, now the southern end of the Isle Royale property. Algodonite was found in the Pewabic mine, located on the Quincy amygdaloid bed and which lies about 5,000 feet higher

\*Amer. Jour. Sci., Vol. X, 1900, p. 439.

†A vein of Whitneyite was long known on the Greenstone bluff near the Cliff mine.

than the Isle Royal amygdaloid. In developing the Mohawk property a cross vein at right angles to the copper-bearing amygdaloid was met in December, 1899. This cross vein was from 12 to 15 inches wide when struck, but has since shown very varying dimensions. In a gangue of quartz and calcite the copper arsenides have been found in this vein more abundantly than in any of the locations mentioned above. Early in January Mr. Fred Smith, Superintendent of the Mohawk mine, sent me a solid piece weighing from four to five pounds, with the request to make a thorough investigation and report. On January 18th I reported to Mr. Smith that the mineral substance which he had sent me was a new mineral species which I would call Mohawkite. Later on I received other material from Mr. Smith in which I identified an antimonial domeykite for which I propose the name Stibio-domeykite, and also some very peculiar intimate mixture of Mohawkite with Whitneyite. It appears that the Stibio-domeykite is the more prevalent of the arsenides, and not the Mohawkite as was thought at the start. The vein has since been traced to the outcrop where it was found to form a ridge owing to the quartz in the gangue."

Dr. Koenig gives the following analyses of type specimens:  
 Mohawkite Cu 61.67, Ni-7.02, Co 0-2.20 Fe-trace, As 28.85  
 Stibio-domeykite Cu 72.48, (Fe. Ni. Co) 0.24, As-26.45, Sb-0.78.  
 Algodonite Cu 83.72, (Fe. Ni. Co) 0.08, As 16.08.

*A. C. Lane on sulphides and arsenides.*—Dr. A. C. Lane says\* of the occurrences: "Sulphides and arsenides occur but there is no sign of replacement of native copper with sulphides in depth. The contrary, if anything, is true. It is characteristic that the abundant sulphides are basic with excess of copper. Chalcopyrite is rare. Chalcocite is commoner and occurs in the Baltic and Champion mines in long 'seams' nearly parallel to the strike, not in 'fissures' across the lode. On the other hand the mohawkite occurs in cross-fissures. The algodonite at the Champion mine, according to Dr. Hubbard, is in a seam nearly parallel with the lode.

"*Whitneyite* Cu, As, occurs on the third level of the Champion as well as in Mohawk.† On the whole, however, the sulphides and arsenides are thought to be superficial.

"*Domeykite* Cu, As (or stibiodomeykite with 1.29 to 0.7856% Sb) Sp. Gr. 7.906 at 21° C, occurs like the mohawkite, which is really only a nickeliferous variety, in the Grand Portage vein.

"*Ledouxite* (Cu Ni Co). As may be an eutectic mixture‡.

"*Algodonite* Cu, As, Sp. Gr. 8.383 at 21, C.

\*Keweenaw Series of Michigan, p. 868-869.

†Am. Jour. Sci. (1900) X, p. 446 and (1902) XIV, pp. 404-416.

‡Koenig, G. A. Am. Jour. Sci. (1900) X, pp. 440-446; Richards, J. W. A. M. Sci. (1901), XI, p. 457; Ledoux, Eng. M. J., April 7, 1900.

"*Mohawkite* (Cu Ni Co), As, a nickeliferous domeykite, Sp. Gr. 8.07 at 21° C. carrying about 63-69% copper, 3 to 7% nickel and 0.5 to 3% cobalt occurs in the Mohawk mine on the Kearsarge lode, and at least as far south as the North Kearsarge lode. A speck perhaps was seen in the Central mine section and Rhode Island four at 529 feet.

"It occurs in cross-fissures tightly welded to apparently fresh country rock, and H. V. Winchell thinks it is not a segregation.

"According to some indications the amygdaloids are leaner, harder and cold grey epidotic near these fissures.

"The occurrence of so-called mohawk-whitneyite with more copper, a mixture of whitneyite with a little mohawkite shows the tendency to native copper.

"*Keweenawite* (Cu Ni), As (39-54% Cu 9.7 to 20% Ni) is pale red and occurs with Mohawkite in the Kearsarge lode."

#### ARSENIC IN THE COPPER.

Dr. A. C. Lane says\* of the distribution of arsenic in the copper lodes.

"On the Kearsarge lode Mr. J. B. Cooper's tests indicate that there is more arsenic on the whole steadily to the north. Mohawkite occurs in the Ahmeek and North Kearsarge mine as well as in the Mohawk. The conductivity is 77½ to 81 at the Mohawk, 89-91½ at the Wolverine, 91 at the Kearsarge. In the Calumet Tamarack shoot the arsenic increases going north and down. But the copper from the Osceola amygdaloid under (southeast of) the Calumet has but .0006%. As (conductivity 101) while the Calumet has .004 (conductivity 99.5). The Tamarack copper conductivity is 92 to 96, the per cent of copper in the rock melted being lower. The more coarsely crystallized copper is naturally the purest, but coarse copper from the Wolverine contained 0.12 to 0.003% As. However, the arsenic in the 'matrix' (the country rock) is generally more than in the copper. The Mass and Quincy have an extra low amount of arsenic. In the geologically higher lodes the arsenic is less. If the conductivity is more than 90 the As is less than 0.04. The Calumet No. 2 mineral has 0.015% As relative to the copper contained. Arranged according to conductivity (arsenic) we have—

Franklin Junior 100 and Quincy 101 on Pewabic lode.  
Atlantic mine (near Ashbed) 100.  
Adventure 101, Mass 100 and Michigan 101.  
Victoria 93 to 94.5.

\*Loc. Cit., p. 869-870.

Kearsarge 91.

Wolverine 89 to 91½.

Mohawk 77½ to 81.

Isle Royale 50 to 55.

Copper Range mines, Baltic, Champion, etc. 65 to 45.

Baltic 45 (with 0.19% As).

This is close to the Sheldon and Columbia property and Grand Portage vein from which the arsenides were early described (algodonite, whitneyite, domeykite, etc.).

"It seems to me there are two or three factors involved which need disentangling, and I have not the data yet. The geologically younger lodes often have less As or S. But some of it I think comes from the country rock, for the mineral sent to the smelter may run from one-tenth to one-third rock, and some from arsenides and sulphides of the fissures."

#### COPPER OXIDE, SILICATE AND CARBONATE MINERALS.

These minerals are only occasionally encountered and do not occur, so far as known, in commercial quantity. One deposit at the Algomah property shows black melaconite ( $\text{CuO}$ ), green chrysocolla ( $\text{Cu SiO}_3 + 2 \text{H}_2\text{O}$ ) and green malachite ( $\text{Cu CO}_3 \cdot \text{Cu (OH)}_2$ ) in irregular masses, and also a veinlet in a brown melaphyre. The deposit follows the bedding of the rocks, making bodies of varying thickness along the strike.

In several cases the green copper minerals have been found in drill cores, especially in the felsites in Ontonagon county. In one opening, on the Indiana property, carbonate and silicate with some native copper have been encountered at a depth of 1,140 feet in felsite.

#### ACCESSORY MINERALS CONTAINING FLUORINE, BORON OR TUNGSTEN (APOPHYLLITE, FLUORITE, DATOLITE AND POWELLITE.)

*Apophyllite* (hydrous silicate of calcium and potassium with some fluorine).

The occurrence of apophyllite has been noted by several writers who discuss the significance of its fluorine content in regard to origin of the deposits. The mineral is comparatively rare and the specimens collected are nearly, if not all, from a few fissure veins. Prof. A. E. Seaman has found numerous specimens at the Phoenix, St. Clair and Clark mines in Keweenaw County, but states that he has seldom seen it in Houghton county.

An analysis by L. J. Smith of one specimen, shows 0.96% fluorine.

*Flourite* (Calcium flouride  $\text{Ca F}_2$ ).

According to Prof. A. E. Seaman flourite occurs in some veins in the Eagle River district. Recently it has been found in small quantity in the shaft at the Indiana Mine, Houghton County.

*Datolite* (A basic orthosilicate of boron and calcium,  $H Ca B Si O_6$ ).

Is a fairly common mineral in the copper deposits, occurring both in the fissure veins and also in considerable quantity as rounded masses in the amygdaloid lodes. An analysis of the common white compact variety by Chandler shows  $SO_2$ -37.41,  $B_2 O_3$  21.40,  $Ca O$  35.11,  $H_2O$  5.73, ( $Al_2O_3$ ,  $Fe_2 O_3$ ) 0.35.

*Powellite*.—Dr. G. A. Koenig and Dr. L. L. Hubbard have described\* specimens of powellite found in the 21st level of No. 8 shaft, South Hecla, Calumet conglomerate lode.

They describe it as a pale bluish green tetragonal mineral with vitreous lustre having one distinct and one imperfect cleavage. Analyses showed it to be essentially calcium molybdate containing tungsten. Two analyses made by independent methods showed:

	$MoO_3$	$WO_3$	$CaO$	$MnO$	$Fe_2O_3$	$SiO_2$	Sum.
I.....	65.74	4.50	27.41	.....	Undet.	.....	97.65
II.....	67.84	1.65	27.30	0.16	0.96	1.52	99.43

The methods for estimation of tungsten give the percentage only approximately, one figure being probably too high and the other too low.

#### SILVER IN MICHIGAN COPPER DEPOSITS.

Silver occurs in many, and probably all, of the copper lodes. It is present only in very minor quantity compared with the copper, but it is by no means negligible. The ore is not all treated for its silver and the actual amount mined is therefore not definitely known. The ores known to contain appreciable amounts of silver are treated separately from the others at the smelters and the copper is cast in anodes in order that the silver may be recovered electrolytically. Some silver is also recovered by hand-picking metallics at the mills. The total production of silver for the past four years is reported by B. S. Butler, in the U. S. G. S. reports on Mineral Resources, as follows:

\*Am. Jour. Science, Vol. XLVI, Nov., 1893, pp. 356-358.

## MICHIGAN COPPER DEPOSITS.

## PRODUCTION OF SILVER FROM MICHIGAN COPPER MINES.

Year.	Ounces silver obtained by picking.	Tons ore yielding copper treated for silver.	Pounds copper treated electrolytically for silver.	Ounces silver recovered electrolytically.	Ounces silver per ton of ore treated for silver.	Total ounces silver recovered.	Value of the silver.
1908....	3,595	1,494.339	26,786.485	237,460	0.1589	241,055	\$127,759
1909....	1,364	1,500,000	31,500,113	285,066	0.19	286,430	148,944
1910....		1,518,000	34,189,526	330,500	0.2176	330,500	178,470
1911....	513	2,300,000	43,755,777	496,768	0.216	497,281	263,559
1912....		2,500,000	45,570,130	528,453	0.211	528,453	324,999

The silver, like the copper, occurs as the native metal. Frequently small masses of copper and silver are found intergrown—forming so-called half-breeds. It has frequently been pointed out that the metals are not alloyed; but are simply grown together and can be easily separated by mechanical means. According to several writers, silver was more abundant nearer the surface than it is at great depths. The descriptions also indicate that it was more abundant in the fissure-vein mines of Keweenaw County, than it is in the bedded deposits now being worked.

## CHAPTER V.

### THE COPPER DEPOSITS OR LODES.

The numerous lodes which have been worked more or less successfully will be described in alphabetical order. The chief producing lodes are the Calumet conglomerate and the Kearsarge, Baltic, Quincy, Osceola and Isle Royale amygdaloids.

#### ADVENTURE NO. 4 LODE.

The chief production at the Adventure mine, which was unprofitably operated for some years, was from lodes in the horizon of the Mass mine lodes described later. The recent work has been of an exploratory nature. The following remarks apply to the unusual type of deposit encountered in the recent openings.

In the cross at 1,500 feet level south from No. 3 shaft, there is exposed a fine grained greenish rock which carries in places some native copper. The rock resembles some epidotic felsites, but microscopic examination shows it to be distinctly fragmental. It is composed largely of quartz, epidote and rock grains. The latter are very dense and largely composed of feldspar and quartz. Many of them are probably felsites, but they are red stained and the texture is obscured. One section shows numerous copper particles with quartz and epidote between the sand grains. Some copper occurs in and has probably partly replaced the grains themselves. Some copper extends in a continuous mass from the quartz-epidote cement through the sand grains. It seems likely that the copper was not deposited with the sand but was brought in later and replaced constituents of sand grains and cement.

Below this light colored sandstone there is a dark brown sandstone containing much quartz and epidote, with some feldspar and calcite and numerous rounded grains of black oxide, probably magnetite, and red patches, probably hematite.

Above the sandstones is a brown mottled much fractured trap containing masses of green epidotic rock which frequently carries copper. The trap is largely made up of altered feldspar and dark green chlorite with numerous black grains and irregular red patches. One specimen of trap shows numerous minute grains of copper in a feldspar crystal.



## ALGOMAH LODE.

The Algomah lode is the upper portion of a brown colored amygdaloid. It differs from the other lodes in carrying black oxide, green silicate and green carbonate of copper instead of the native metal. Along the strike it shows great masses of green colored ore, more or less separated by stretches of brown amygdaloid. Sixty tons of selected ore was sampled and said to yield assays of 24% copper. Development has not proved a large body of good ore however.

The copper oxide in the Algomah lode occurs chiefly as dull black massive melaconite, but Prof. A. E. Seaman has found specimens showing black tetragonal crystals of paramelaconite in green malachite.

The lode strikes nearly north and dips to the west at an angle of about 70° at the shaft. It is close to the eastern sandstone and the northern drift on the lode intersected the great Keweenaw fault and the sandstone.

## ALLOUEZ CONGLOMERATE.

This lode is not now being worked;\* but it contains considerable copper in places and may be opened up again at an early date.

*At Allouez Mine.*—Some characteristics of this lode are given in Chas. E. Wright's account of operations at the Allouez mine in 1882. He says:†

“The center of the main ‘shoot’ of copper crosses No. 2 shaft at about the eighth level and makes with the vertical an angle of 30°, opening upward to the south.

“A remarkable ‘slide’ extends down through the mine from the surface 200 feet south of No. 1 shaft, and pitching to the north at an angle of 60°, crossing No. 2 at the thirteenth level. This slide is soft clay loam, crossing the formation. The tenth level is extending south to intercept a good shoot of copper that has been found to follow the slide. During the past year the eighth, ninth and tenth levels have been driven north to nearly No. 3 shaft, and the main copper shoot of the mine is found to continue to these levels.

“The lode bears north 39° east, and dips 38° northwesterly; it is a very wide, coarse, conglomerate belt, corresponding with that which further north immediately underlies the greenstone. It is the same belt which is now being opened at the Delaware—Conglomerate Mining Company—though, at the latter mine it is claimed that the belt is richer in copper than it is at the Allouez. They find richer specimens at the Conglomerate than are found to occur at the Allouez, and likewise limited portions of the lode that carry more copper, but to what

\*Since this report was written the lode has again been opened up at the Franklin Jr. mine.  
†Report Com. Min. Stat. Mich., 1882, p. 82.

extent this will affect the average yield to the advantage of the former company remains to be seen. Here, as at the Conglomerate, the belt is very wide—twenty to thirty feet in width—much too wide to work to advantage.

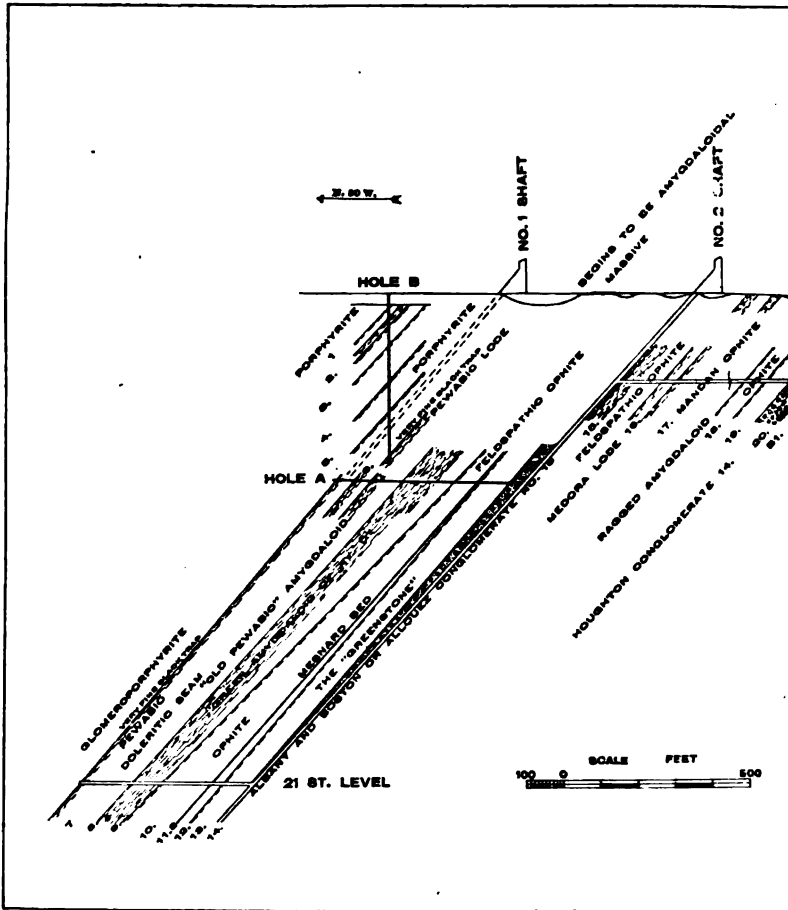


Figure 4. Section at Franklin Junior mine showing Pewabic and Allouez lodes (after Lane).

“The drifts are carried along the foot wall, and four feet or five feet of the conglomerate are left next to the hanging to help support it. The hanging wall is exceedingly poor, and requires frequent pillars to be left, together with considerable thickness to the bottoms of the drifts and a portion of the lode in contact with the wall, to support it.

“The lode is not uniform in richness. The copper appears to be

in seams, where it occurs, alternating, in streaks. It is exceedingly lean in copper, but requires to be all taken down and subsequently sorted, and even then very much of it is stamped that is really worthless."

"They have stamped during the year (1881), 74,538 tons of rock, which yielded 969 tons, 860 pounds of mineral, which, smelted, gave 710 tons, 1,403 pounds ingot copper. Number of tons rejected was 12,837, 1-7 of whole number of tons hoisted."

The yield per ton from the ore mined in 1881 was 19 pounds copper.

*At Franklin Jr. Mine.*—Thomas Macfarlane says\* of the conglomerate mined by the Albany and Boston Mining Company (now Franklin Junior):

"The boulders and pebbles consist of various species of porphyry. One of them has a dark brown matrix with small white crystals of feldspar; another has a matrix of the same color, but with larger crystals of orthoclase, while a third variety consists principally of a fine grained mass of orthoclase, with which a small quantity of a dark colored mineral occurs in particles too small for determination. The matrix consists of a coarse grained sand of porphyritic material, impregnated with calcareous matter. In many places the interstices are not at all filled up, in other calcspar is the matrix, and very often, in the lower part of the bed, the matrix is almost all pure metallic copper. Sometimes the metal completely fills the whole space between the pebbles, sometimes it is accompanied by calcspar, but much more frequently is disseminated in fine particles through the coarse grained matrix. Sometimes a pebble is found quite saturated with copper, but it seems to have been of a more porous nature than the others, and an amygdaloidal structure may be detected in it.

"As above mentioned, a bed of sandstone underlies the conglomerate. It shows traces of stratification, is of a dark-red color and evidently of the same material as the conglomerate pebbles but in finer particles."

At the thirty-second level of the Franklin Junior mine a cross cut has been run from the workings or the Pewabic lode to test the Allouez conglomerate which had not been previously opened up at so great a depth. Where cut at the thirty-second level the conglomerate is thick and shows considerable copper.

#### ASHBED LODGE.

The Ashbed lode is an amygdaloidal porphyrite which has been worked at several mines in Keweenaw county. It was frequently first opened incidentally in working fissure veins and commonly was then found richest where traversed by the veins. It has for some years not been

\*Report Geological Survey of Canada, 1866. pp. 156-157.

worked, but the Keweenaw Copper Company has begun a thorough investigation of its possibilities.

The bed lies comparatively flat, being commonly inclined at an angle of less than 30°. This flat dip does not permit the broken ore to run freely down the stopes, and thus increases the cost of handling the ore. This difficulty is partially offset by the fact that the lode is rather easy to drill and break.

The Ashbed derives its name from the character of the upper part of the lava flow. This has a conglomeratic character due to mixture of large volcanic fragments with ash and mud.

Chas. L. Lawton says\* of the lode at Copper Falls Mine:

"The rock yields about 0.7% copper. The lode is but seven feet in width and lies at an angle to the north of about 27°. \* \* \* The Ashbed is faulted at three different points in this mine, west of the main adit. The main faults are 65 feet and cause a good deal of dead work in the drifts in each level. The Ashbed mines very cheaply. The main drawback is in the matter of getting the rock down from the stopes."

#### ATLANTIC LODE.

*General character.*—The Atlantic Lode is comparatively low grade bed but was for several years worked profitably by the Atlantic Mining Company. In its best part it yielded only from 13 to 14 pounds copper per ton and as the workings were extended north and south and deeper the yield fell to 11 and 12 pounds. That the lode was profitable at all is due to the fact that this yield was obtained by continuous stoping. The copper was not very regularly scattered through the lode, but neither was it confined to portions which could be readily selected from waste rock. The whole lode was broken and an unusually low cost per ton thus obtained.

The rock in which the copper occurs is, according to Dr. Hubbard, a melaphyre conglomerate. The fragments of melaphyre, commonly amygdaloidal, are cemented by dark reddish sandy material which is in places greenish with epidote. This conglomeratic character is more noticeable in the upper part of the lode, while the lower portion is a dark brown amygdaloid. The Atlantic mine has been idle for several years, having caved in 1906.

*Dr. L. L. Hubbard's description.*—Dr. L. L. Hubbard's description† follows:

"The bed worked by the Atlantic Mining Co. is in part a melaphyre conglomerate,‡ being made up of fragments of amygdaloidal melaphyre in a matrix of fine but more or less angular basic sandy material, in

\*Rep. Com. Min. Sta. Mich., 1885, p. 224.

†Geol. Sur. of Mich., Vol. VI, Pt. II, p. 137.

‡Pumpelly's description tallies with this designation. Ibid 1, Pt. II, p. 77.

places altered to epidote. The copper-bearing belt extends down into the unbroken amygdaloid. This and the underlying trap belong to the more basic lavas and have no immediate resemblance to the typical Ashbed rock as we find it on Keweenaw Point as far south as the Tam-rack mine, other than in the fine dissemination of the copper which it carries. The Ashbed rock shows abundant greenish to reddish crystals of feldspar."

*C. Rominger's description.*—C. Rominger says\* of the Atlantic lode:

"The Atlantic Mine, situated about one mile south of its stamp works, is opened in a large dark brown colored amygdaloid belt, overlain by a conglomerate belt fifty feet wide. This amygdaloid belt has in part the character of a breccia composed of irregular larger and smaller blocks and rounded masses of a brown colored amygdaloid full of cavities, filled principally with calcspar and laumontite, but also quartz, prehnite, delessite, epidote and copper take part as filling-materials, either one alone or several of them associated, and of a cementing groundmass of the same brownish color as the inclosed amygdaloid masses, which exhibits distinct sedimentary lamination. The surface of the inclosed rounded masses of the amygdaloid is sometimes coated with a polished crust, streaky like slickensides; other times their pitted surface is shining as if glazed by exposure to fire.

"The copper is quite unequally distributed in this rock belt; the richer portions of it are copiously interspersed with larger shotlike grains and also with branching hackly masses of the metal which have moulded themselves after the shape of pre-existing fissures and cavities in the rock; much of copper is also contained in the amygdules in association with the other mentioned minerals.

"Other portions of the belt are poor and the copper contained in them occurs in smaller molecules. Practically no selection is attempted of the poorer rock from the richer, the entire width of the rock seam is taken out and the material run through the stamp mill."

*Production.*—Chas. L. Lawton says† of this lode:

"It is a comparatively soft amygdaloid, not so soft but what it breaks well under the action of blasts. It averages 10 feet in width and is uniform enough to permit its all being stoped."

Mr. Lawton gives the figures on yield per fathom for years 1875-1888. The figures for following years are from the annual reports.

\*Geol. Sur. of Mich., Vol. V, Keweenaw Group, p. 97.  
†Report, 1888, p. 28.

## PRODUCTION OF ATLANTIC MINE, 1875-1902.

Year.	Tons ore stamped.	Ground broken, fathoms.	Yield of copper per fathom broken.	Yield of copper per ton (in pounds).	Remarks.
1875.....	80,000	.....	278	19.58	
1876.....	96,696	.....	280	18.99	
1877.....	105,780	.....	290	19.42	
1878.....	121,709	.....	243	18.50	
1879.....	112,668	.....	266	19.00	
1880.....	169,825	.....	244	14.27	
1881.....	176,555	.....	2,735	14.36	
1882.....	189,800	.....	259	13.866	
1883.....	195,669	.....	240	13.708	
1884.....	209,510	.....	259	15.1	
1885.....	241,010	.....	267	14.86	
1886.....	247,035	.....	238	14.18	
1887.....	255,750	.....	234	14.24	
1888.....	298,055	.....	228	13.34	
1889.....	278,680	16,155.9	228.9	13.272	
1890.....	278,300	18,819.8	192.3	13.0	
1891.....	297,030	20,591	177.4	12.3	"Falling off in 1891 probably due to extension of openings north and south of the central portion of the mine where the best ground is located."
1892.....	300,900	17,811	207.9	12.31	
1893.....	315,670	18,398	229	13.375	
1894.....	315,626	20,243	219	14.06	
1895.....	331,058	20,037	241	14.6	
1896.....	371,128	20,629	237	13.19	
1897.....	394,296	24,429	209	12.96	
1898.....	370,767	20,438	214	11.8	"Lower grade ore from new 'A' shaft, falling off due largely to increased production north and south."
1899.....	380,781	22,101	211	12.28	
1900.....	410,674	23,071.5	213	12	
1901.....	409,124	24,883	187	11.4	
1902.....	446,098	25,764	192	11.095	

## BALTIC LODGE.

*General character.*—The Baltic lode is the cupriferos upper portion of a thick bed of melaphyre. It is in part amygdaloidal, but in part also dense brown trap which is more or less shattered and seamed with secondary minerals, especially calcite. The amygdaloid portions have commonly a gray or brown ground mass and amygdules of white calcite. The trap is a brown melaphyre spotted with dark green chlorite—a pseud-amygdaloid. Very little of the copper occurs as a filling in amygdaloidal cavities, and much of it is not in amygdaloid at all. The lode differs therefore from the regular portions of typical amygdaloid lodes and fracturing has been largely responsible for the formation of cavities in which the copper was deposited. This character has been noted by several writers and is expressed by Dr. Lane in the statement that "the Baltic lode is not one well defined amygdaloid top to a flow, but rather an impregnated shear zone or stockwerk, copper being found over a belt more than 40 feet wide." The footwall trap is, according to Dr. Hubbard, from 100 to 150 feet thick for a length, at the Baltic and Champion mines, of four miles. In the hanging wall of the main lode there is a second smaller deposit, known as the "West lode,"

which has been opened in several places by crosscuts or 45° raises. It has yielded good ore in some parts of the Champion and Baltic mines.

The Baltic lode is a wide one, being commonly from 15 to 60 feet and in some places 80 or 90 feet. The thickness at the mines averages about 24 feet. At the Baltic mine the lode strikes N. 60° E. and dips 73° N. W. This dip is much steeper than that of any of the other lodes being mined. At the Champion mine the Baltic lode strikes N. 26° E.

Fissures are numerous in the lode and at some of the mines faults and soft seams cut across it at short intervals. Many of the fissures are filled with calcite, making conspicuous, though usually very narrow white veins running across the dark colored rock. Many others are filled with soft greenish and reddish material, chloritic, talcose or clayey. These soft seams have apparently resulted from crushing and slipping. Often in such ground the lode is displaced many times

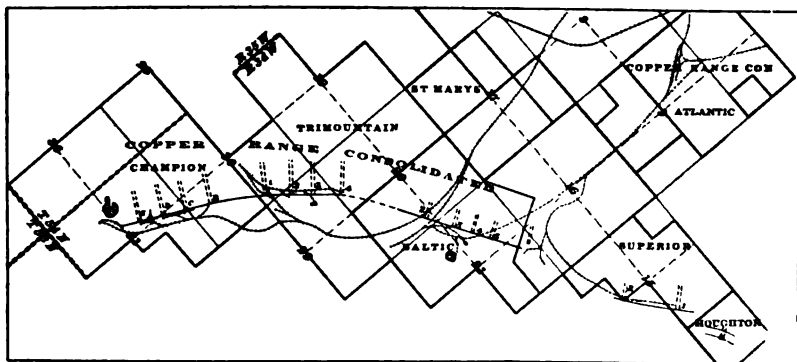


Figure 5. Map showing mines on Baltic, Superior and Atlantic lodes.

in a short distance. Numerous narrow veins of calcite run parallel to the bedding and some contain chalcocite.

*Distribution of the copper.*—In parts of the lode, the copper is distributed rather evenly through the rock and little selection is then possible. In other places however, the copper is in bunches separated by very low grade or barren rock and the good ore is readily sorted out and the waste is used for filling the stope. As a rule the rich portions of the lode show copper very conspicuously and often include numerous masses. In places the copper, while all in small particles and not showy, is very evenly distributed through the rock giving an ore which is comparatively low grade, but not mixed with barren rock.

The main production of the Baltic lode is from a three mile stretch worked at the Champion, Baltic and Trimountain mines. Further

northeast, operations on the Baltic lode have disclosed ore at the Superior and Houghton mines. Here a lode known as the "Superior lode" is about at the horizon of the Baltic lode and is thought to be a continuation of it. On the intervening properties no important ore body has been found. At the Atlantic section 16 shaft, the lode was found to be very badly fractured, faulted and crushed, and there was great difficulty in identifying horizons. The ore bodies were repeatedly cut off by faults and the workings were seldom in ore for any considerable distance. At the Superior mine the lode is also much fractured, but a large body of good ore has been blocked out at one shaft. Similar ground has been found also further north at the Houghton mine shaft.

At the Champion, Trimountain and Baltic mines the lode is comparatively firm. There are numerous fissures, but the ground has not been so severely disturbed as further northeast. In some places at the Baltic and Trimountain mines the lode is more broken up and between the Trimountain and Baltic mines there is a disturbed area accompanying a marked change in strike of the lode. It is generally supposed that there has been considerable faulting here.

At the Copper Range mines, Champion, Trimountain and Baltic, the ore is commonly sorted and the waste rock is used for fill. The sorted ore from the different mines in 1912 yielded 19 to 22.5 pounds copper per ton. At the superior mine the ore is of quite different character, much of the copper being in very fine particles, and sorting is not practiced. The ore mined from this lode at the Superior in 1910 averaged 22.64 pounds per ton. At present much of the ore from the Superior mine is coming from a second deposit known as the West lode, which is described elsewhere in this report.

*Future production.*—None of the mines on the Baltic lode have yet reached very great depth and its future yield can only be roughly guessed at. In 1911 Mr. J. R. Finlay estimated that the lode should produce 15,000,000 tons of ore containing 311,000,000 pounds of copper. This estimate is based on a lesser depth than that of the other great lodes and will be much exceeded if the ore persists with depth.

*L. L. Hubbard on Baltic lode.*—Dr. L. L. Hubbard in Vol. VI, of the publications of the Survey says\* of the Baltic lode:

"The Baltic mine is in an amygdaloid bed, whose strike according to Mr. Theodore Dengler, Mining Engineer of the Atlantic and Baltic mines, is N. 60° 30' E. (Magn.). This bed crosses the line between sections 20 and 21, T. 54, R. 34, about 200 feet north of the quarter-post. It shows some slight evidence of disturbance, in the nature of shearing or slide-faulting, in the presence of several small fissures that strike with the bed and are nearly vertical; they are filled with a

\*Page 135, Vol. VI, Keweenaw Point.



carbonate of lime and carry some chalcocite. These fissures appear to wedge out at a short depth from the surface. Other irregular seams cross the rock, filled with calcite, this being also the usual filling of the amygdules. The latter are irregular in shape, and in places almost look as if they were secondary, i. e., pseudoamygdules, due to the filling of irregular cavities or pores induced by chemical or by mechanical changes, or by both. The calcite is of earlier origin than the copper found associated with it, the latter showing the mould of the cleavage and twin-planes in the former. On being exposed to weathering the calcite becomes yellow from a small percentage of iron in it. The dip of this bed is about 73° to the northwest."

#### CALUMET CONGLOMERATE LODE.

*General character.*—The Calumet lode is the cupriferous portion of one of the conglomerate beds interstratified with the volcanic rocks of the lower Keweenawan. The conglomerate is a thin bed which has been traced more or less continuously for several miles. The ore bearing portion is almost entirely confined to that part, about two miles long, which outcrops on the property of the Calumet and Hecla Mining Company and which at depth crosses into the property of the Tamarack Mining Company. On other properties north and south it has been extensively worked but with the exception of a small area at the Tamarack Junior Mine, proven unprofitable. The conglomerate is overlain and underlain by thick beds of trap, chiefly coarse ophites.

The conglomerate rock mined is made up largely of pebbles of felsite and quartz-porphry cemented together with small particles of rock, calcite and native copper. The cementing material commonly contains also iron oxides, quartz, epidote and chlorite. Much of the iron oxide is martite, a pseudomorph of hematite after magnetite. While most of the pebbles are silicious rocks, some are melaphyres or porphyrites.

The conglomerate is characteristically red, both pebbles and cement being commonly of that color. Near the surface it is somewhat redder than at depth. Most of the constituents are of light tones, but parts of the lode are largely made up of dark reddish brown pebbles. Most of the lighter colored pebbles, light red or flesh colored, are dense felsite or quartz porphyry. The darker colored ones have usually a finely felsitic ground mass and phenocrysts of brown red feldspar. Other dark brown ones have a very dense ground mass enclosing phenocrysts of quartz. Some are dark colored felsitic rocks with no phenocrysts. Many pebbles show an outer rim of lighter color than the interior. This results from alteration.

The small rock particles in the matrix are similar in character to the pebbles, but have been more extensively altered.

*Occurrence of the copper.*—The copper occurs chiefly as part of the cement, filling spaces between sand grains and pebbles, but some has replaced the rock constituents. It is a common occurrence to find large pebbles partially replaced by native copper. Mr. Chas. L. Lawton says in one of his reports that of the 47,247,990 pounds of copper recovered in 1885 about two per cent was from the “nigger heads” or small copper boulders. While most of the copper is coarse, much of it is in very minute particles and the ore has to be finely ground to avoid heavy losses in sand tailings.

*Light and dark portions.*—Where a large section across the lode is exposed, as in the drifts and stopes, there are usually to be seen rather distinct light and darker colored portions. The copper is chiefly in the light colored rock. The darker colored portions are noticeably more compact and less altered than the lighter. They have evidently not been much affected by the solutions which in more porous parts altered the rock and deposited native copper.

*Sandy portions.*—In places the conglomerate grades into a sandstone made up of particles similar to the cement of the conglomerate. The sandstone sometimes is locally heavy with copper, giving the so-called “brick” copper, but more commonly the sandstone portions are comparatively lean and often barren.

*Thickness.*—The thickness of the lode, as determined by mining operations, is from 10 feet to 20 feet. Near the surface at the Calumet mine the lode is said to have averaged about 13 feet, at some levels at great depth at the Tamarack mine about 22 feet and at similar depth further south in the Hecla mine about 10 feet. In the upper levels the lode was much thicker at the south Hecla shafts than at the Calumet shafts, but not so rich. According to Capt. Daniell, the thin portions “seem to occur in spots rather than in regular courses.” The average thickness of the ore still to be mined by the Calumet and Hecla Company is said to be about 15 feet.

*Distribution of copper.*—As a rule the values are irregularly distributed from wall to wall. In places the poorest part of the lode is near the hanging wall, and in other places the upper portion is the richest. In extensive workings tributary to one deep shaft the portion next the foot wall was always the least productive.

*The Calumet shoot.*—The richest part of the lode was that opened at the Calumet shafts and which forms a very large shoot pitching north at about 70°. While production was largely from this shoot the ore averaged over five per cent copper and yielded over four per cent refined copper. The available records do not show definitely



how the values held with depth, as the production from other leaner parts of the lode became larger in 1887 and the product is not distinguished. It is known, however, that the values at the fortieth level were still practically as high as in any of the levels above. As near as can be judged from the available records, the Calumet ore shoot for over a mile downwards on its pitch of  $70^\circ$ , continued with

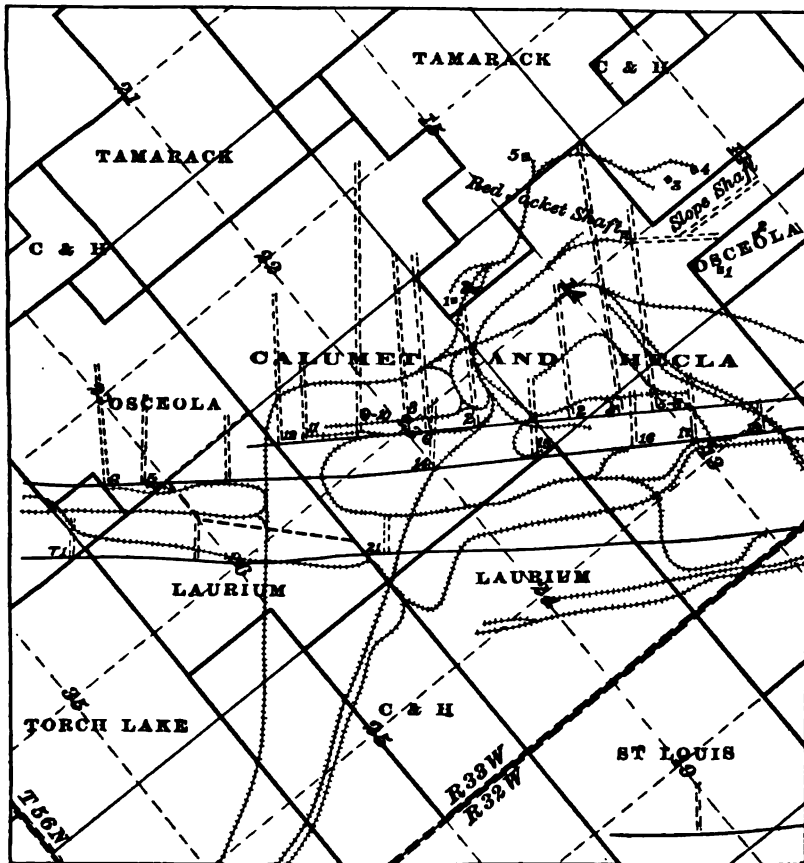


Figure 7. Map showing Calumet and Hecla and Tamarack mine locations.

fair regularity to yield over four per cent copper and then, below the 57th level, yielded ore of much lower grade.

*The leaner portions.*—Aside from this main ore shoot and other smaller and less rich shoots in the southern portion of the property, the conglomerate usually contains enough copper to pay for mining. Some very large blocks have been left as unprofitable ground and

numerous smaller blocks are left in different parts of the mine. It is not customary to do much sorting of broken ore in the mine and the poor ground is as far as possible left unbroken. The broken rock is practically all hoisted and a little, chiefly hanging wall trap, is discarded at surface. The trap is in places very weak and a little of the lode is commonly left on the hanging to provide a better roof for the openings. Not infrequently however, some of the trap breaks and becomes mixed with the ore.

*Strike and dip.*—At the Calumet mine the conglomerate lode strikes N. 33° E. and near surface dips to the N. W. at an angle of about 38°. At the South Hecla mine the dip at surface is about 39°. At depth the angle of inclination is slightly less than at surface. One shaft, following the lode closely is inclined at 38° down to the 36th level and below that at 37° 30'. Dr. A. C. Lane in a section across the lode at one shaft gives the dip as 37° 10'.

*"Brick" copper.*—At the Calumet mine the conglomerate contains numerous sandstone streaks. These as a rule are thin and pinch out quickly, being of lenticular form; but in some places the sandstone layer is of considerable extent. There is frequently a good parting along the bedding of the sandstone and it is stated that such surfaces often show distinct ripple marks. Generally the sandstone contains very little copper, but on the other hand there are some thin bands two to three inches thick which are very rich. The copper is in a fine red sandstone made up of rock and mineral fragments of the same kinds as is the coarse conglomerate. Much of the sandstone is of a greenish gray color made up largely of quartz and epidote and commonly barren of copper.

In some places the thin red sandstone seams contain enough copper to pay the whole cost of mining and treating 12 feet of conglomerate. It is stated that some of these seams contain as high as 80 per cent copper.

*The hanging wall.*—The hanging wall of the conglomerate is a dense trap which has a good fracture plane at a distance of about one to two feet from the contact. In places there is vein material along this face and it appears to be a fissure along which some movement has taken place and which has been subsequently filled, chiefly with calcite. When exposed to the air the calcite crumbles and the roof breaks off easily thus necessitating care to prevent the fall of the "cab" as it is called by the miners. It is common practice to leave a little of the conglomerate on the hanging wall, to avoid disturbing the cab. Except where the lode is rich, the saving in cost of mining more than compensates for the loss of copper left in the conglomerate.

In the upper levels at the south end of the property there is a mud

seam about four inches thick at the contact between the lode and the overlying trap.

*Early openings at Tamarack mine.*—Chas. L. Lawton describes the portion of the conglomerate first opened at the Tamarack mine. He says:\*

“The lode averages about 12 feet wide, and so far as opened is all good ground, that is, all the vein carries copper; not in equal amount, however; some of it is very rich, but the rich rock and the poor are everywhere, in all parts of the lode. If a light is thrown upon a smooth, vertical section of the deposit, it shows the rich and poor rock nicely; the dark, barren portions are strongly contrasted with the segregations of light colored rock richly impregnated with mineral—a small amount of rock—five per cent—is rejected; this comes in part from the hanging, but also, mainly, from a deposit of sandstone that occurs in the vein south of the shaft. It is of variable width, but at no place takes more than five feet of the vein; sometimes against the hanging and again leaving a few feet of rich conglomerate between it and the hanging; in places it is simply a thin seam and wedges out entirely. So far they have no rich shoots of copper, as are found in the Calumet and Hecla, to bring up the average percentage.”

*At Tamarack mine in 1896.*—Supt. W. E. Parnall said in his 1896 report on the Tamarack mine:

“The mine from the 12th to the 21st level (No. 1 shaft) opened lean, except in patches, compared with the ground above. Being confined to comparatively narrow limits, considering the output of rock, there was no chance for special selection, nor would it have been good mining to leave behind and expose to absolute loss ground on which a small profit could be made. This, I am pleased to state, has been struggled through.”

South of No. 1 shaft there was a “crossing” or fault and near this the lode was poor. Supt. Daniell refers to it several times in his reports. He says in his report for 1889: “The 6th level has in all been opened for a length exceeding 800 feet and, excepting 50 feet in length of lean ground in the vicinity of the ‘crossing,’ has been of excellent quality. The lode in 8th level south narrows from crosscut, and near the crossing is not much in excess of nine feet wide. We drifted through lean ground here; 100 feet in length we scarcely regard as good enough to stope. Beyond or south of the crossing the conglomerate affords fairly good stopping ground, but the lode does not run in excess of 10 feet wide.” Speaking generally of the parts of the lode near the crossing, he says: “We consider that the crossing affects this ground unfavorably.” Regarding the distribution of the copper in the lode he says:

\*Report Com. Min. Stat. Mich., 1885, pp. 243-244.

"I cannot say that the copper courses in the (Tamarack) mine have any particular direction. Ordinarily, when the conglomerate is less than average width it is off in productiveness, but the narrow parts seem to occur in spots rather than in a regular course."

Supt. W. E. Parnall in his report for 1895 says of the portion of the lode first opened up at No. 3 shaft. "It will average 21 feet wide and is made up of very rich and very lean streaks." No. 3 shaft reached the lode at a depth of 4,185 feet where it was 19 feet thick.

*The "crossing."*—Reference to the "crossing" is also made by Supt. Daniell in the 1886 report of the Tamarack Mining Co. He says: "In the workings of the Hecla mine a 'crossing' or fault running nearly at right angles to the lode and enclosing strata has been noted. It heaves or dislocates the beds of rock, the displacement being generally equal to, or greater than the thickness of the conglomerate, say from eight to ten feet. This, for a long time was regarded as the southern limit of the copper ground, and in its vicinity the lode has not been of average quality. As we pushed south at the second and third levels (Tamarack No. 1) we encountered several small fractures running across the conglomerate, and recently found, at 210 feet from the shaft the 'crossing.' At this point the throw is fully eight feet, the southern extension of the lode being towards the west or hanging wall."

*Tamarack ore.*—At Tamarack No. 3 according to Dr. Lane, the main good shoot of copper ground coming in from the Hecla (or "Black Hills") end of the Calumet comes in according to Capt. Rosevear, in the 15th level at 1,300 feet; and on the 18th level at 600 feet. Dr. Lane remarks that the damp ground is said to be better copper bearing.

*Mine water.*—Dr. Lane states\* that "The Calumet conglomerate water is relatively fresher than that in the amygdaloid rocks around it on either side; but this difference seems to disappear somewhat at great depth or at least that the ratio of Ca:Cl becomes about the same. The copper is richest in the middle water and becomes very slowly less rich as the lower water is reached, but continues good long after the lower water is well established and the Ca:Cl ratio has become 0.485."

*At Osceola mine.*—Chas. L. Lawton says† of the Calumet conglomerate as opened up at the Osceola mine.

"The conglomerate (C. and H.), which underlies this west amygdaloid has in places a remarkably good hanging wall. Where it was worked out ten years ago in large chambers the roof remains perfect. At other points it was broken up. Where the hanging is broken and poor the conglomerate is said to have carried copper, but in the portion having a firm hanging, the conglomerate was proportionally barren,

\*Keweenaw Series, Pub. 6, Mich. Geol. Sur., p. 811, 1909.

†Report Com. Min. Statistics, 1885, p. 248.

and the amygdaloid was good—giving rise to the theory that the broken rock between the lodes allowed the copper to pass from the amygdaloid into the conglomerate.”

*Production of Calumet conglomerate lode.*—The conglomerate has yielded more copper than any other lode on Keweenaw Point, and the metal has been won at a cost which has made the Calumet and Hecla the leading dividend producer among the mines of the world. Mr. J. R. Finlay estimated, in 1911, that the Calumet and Hecla had still on the conglomerate lode about 27,000,000 tons of ore which should yield 26 pounds per ton—a total of 702,000,000 pounds of copper. Another estimate in the same year was 30,000,000 tons yielding 30 pounds per ton, a total of 900,000,000 pounds. On account of great depth and lower values, the Tamarack yield for the future is very problematical.

The following table from “The Mineral Industry” shows the output for Calumet and Hecla for several years. It will be noted that for the period from 1875 to 1886 the yield was remarkably uniform. During this period the Calumet mine was deepened to the 30th level, and the output was largely from the main Calumet ore shoot. Subsequently a much increased tonnage came from other shafts. Beginning in 1887, there was a large production from the Black Hills or South Hecla shafts. After 1891 for several years the yield was not made public. For the past few years it has been about 1.5 per cent.



## MICHIGAN COPPER DEPOSITS.

## PRODUCTION OF CALUMET AND HECLA MINE, 1767-1891.

Year.	Ore milled, short tons.	Pounds refined copper produced.	Yield, per cent.
1867		1,351,173	
1868		5,098,375	
1869		c12,315,771	
1870		14,061,584	
1871		16,222,590	
1872		16,183,836	
1873		18,848,265	
1874		20,125,225	
1875	249,704	21,473,954	4.30
1876	259,935	d21,690,737	4.17
1877	247,935	22,568,468	4.55
1878	271,000	25,251,128	4.66
1879	284,715	26,271,243	4.61
1880	334,343	31,675,239	4.75
1881	340,080	31,360,781	4.61
1882	344,132	32,053,540	4.59
1883	372,570	33,125,045	4.45
1884	435,352	40,473,585	4.63
1885	535,820	47,247,990	4.40
1886	598,522	50,518,220	4.22
1887	654,055	46,016,123	3.52
1888	763,728	50,295,720	3.29
1889	807,918	46,668,206	3.01
1890	i947,700	59,868,106	3.16
1891	h960,309	63,586,620	3.31

cFor 12 months ending December 31, 1869.

dFrom 1867 to 1872, inclusive, the respective reports are for the year ending July 1. From 1873 to 1875, inclusive, the reports are given up to the first of May. In accordance with an act of the Legislature, the form of the report, as well as its date, was changed, the latter being the 31st of December of each year instead of the company's fiscal year. Owing to this change the year 1876 is carried to December 31 and covers 20 months.

hThis figure represents the tons transported from mine to mill over the Torch Lake Railroad.

iEstimated from best available data.

For a number of years no public statement of production was made. The yield fell off with depth and with lateral extension of the openings. The southern Calumet shafts passed on through the rich ground which pitches to the north. The northern Calumet shaft after being for many hundred feet in lean ore entered the rich shoot and continued in it to below the 57th level. Below this lean ore was again encountered. No separate record for the rich shoot is available. The average yield became lower until it is now less than 1.5 per cent. The company has during the past few years published figures showing the quantity and copper yield of ore mined.

PRODUCTION AND YIELD OF CALUMET AND HECLA CONGLOMERATE DURING PAST FEW YEARS.

Year.	Tons of ore stamped.	Pounds refined copper produced.	Yield in pounds per ton treated.	Yield, per cent.
1908	1,958,200	70,427,877	35.96	1.798
1909	1,999,880	66,285,684	33.14	1.657
1910	1,950,040	58,739,509	30.12	1.506
1911	1,924,480	58,469,399	30.38	1.519
1912	1,746,960	51,935,245	29.73	1.486

*The rich portion.*—The richness of the ore mined when the shafts were less than 2,000 feet is shown by the fact that the average yield of refined copper per ton of ore treated in 1874 was 4.28% and in 1875, 4.30%. Probably about one per cent was lost in milling, so the actual content of copper in the ore was over five per cent. Some years later the product was still richer, the output for 1880 yielding 4.75 pounds refined copper per ton from 334,343 tons. The figures indicate that the decrease in contents with increasing depth was by no means a gradual one. For the 12 years 1875-1886 the yield varied from 4.17 to 4.75 per cent. If records for production from the main ore body for subsequent years were available it could be shown that the rich ore continued to much greater depth than the lowest openings which existed in 1886. The yearly record beginning in 1887 shows a much lower average in grade of ore produced; but this was due largely to the fact that in that year began the large production from the lower grade ore opened by the South Hecla shafts.

The rich portion pitches to the north and continues down to the 57th level. Below that level there is said to be comparatively little rich ore in the lode. Long before the 57th level had been reached the increasing output of lower grade ore from outside the rich shoot had brought down the average yield very considerably. Now that the rich portion has been almost completely mined out the average yield is still lower, being in 1912 only 29.3 pounds copper per ton of ore. There is still a little rich ore standing, mostly as pillars, of which a considerable portion will be recovered before the mine is abandoned.

*Rich ore at depth.*—That the lode was in places rich at considerable depth is shown also by the following table of results obtained at the Tamarack mine in years 1886-1893. The stope maps show that there was remarkable continuity of pay ore.

Supt. John Daniell says in his 1886 report on the Tamarack mine. "The extensive development of the conglomerate in the neighboring (Calumet and Hecla) mine had shown its unimpaired productiveness, down to a depth corresponding to our first level." (This was at a point fully 1,000 feet north of the Tamarack No. 1 shaft).

## PRODUCTION OF TAMARACK MINE, 1886-1893.

Fiscal year.	Tons ore stamped.	Refined copper produced.	Yield, per cent.	Remarks.
1886.....	36,129	1,979,400	2.7	
1887.....	90,587	4,636,521	2.6	
1888.....	144,412	10,389,861	3.6	
1889.....	169,250	11,036,469	3.3	
1890.....	155,250	8,928,249	3.9	
1891.....	282,987	14,076,957	2.5	
1892.....	338,700	16,805,360	2.5	
1893.....	345,925	16,061,106	2.32	All ore from below 9th level.

*Chemical composition of the conglomerate.*—Dr. Lane has published, from information furnished by Mr. J. B. Cooper, the following analysis of slime overflows from trough classifiers between stamp-heads and jigs taken at the Calumet mill, September, 1906. It cannot fairly be taken as a sample of the conglomerate but nevertheless gives some idea of its composition.

## Analysis of Calumet Conglomerate Slime.

Loss of ignition.....	5.03%
Si O <sub>2</sub> .....	55.08
Fe <sub>2</sub> O <sub>3</sub> .....	9.04
Al <sub>2</sub> O <sub>3</sub> (+ traces of Ti O <sub>2</sub> ).....	15.41
Ca O.....	7.02
Mg O.....	2.49
Cl.....	0.18
SO <sub>3</sub> .....	0.04
Cu (perhaps with some oxide).....	1.70
K <sub>2</sub> O and Na <sub>2</sub> O.....	Not determined.

95.99

*C. Rominger's description of the conglomerate.*—C. Rominger describes\* the Calumet lode in his report on the Keweenaw Group, 1885.

"The conglomerate belt of the Calumet and Hecla mine averages a width from 12 to 25 feet; its dip varies from 36 to 39 degrees to the northwest. Fully two miles of the length of the belt are on this mining property; the deepest shafts following the inclination of the belt are 2,700 feet long, which makes a vertical depth of about 2,068 feet below the surface. On the entire extension of the property, the conglomerate belt has very few barren spots, and the rock is, without selection, sent to the stamp mills where it yields about five per cent of washed

\*Vol. V, pp. 114-117, Geol. Surv. Mich., 1885.

metal; portions of the rock are much richer, as high as thirty per cent in metal. The product of the mines during the last three or four years was about 16,000 tons of ingot copper annually.

"The conglomerate of this belt is reddish brown colored, hard and compact; locally composed of rather large, rounded pebbles, but the main mass consists of smaller pebbles with many little-worn angular rock fragments among them. The interstitial material consists of smaller arenaceous particles held together by siliceous and calcareous cement; the copper in the rock occupies mainly these interstitial spaces between the pebbles, and is sometimes replacing the cement altogether.

"The union of these fragmental masses is very firm, a stroke of a hammer does not sever their connection, but breaks the mass straight across the pebbles, which, with the exception of a small proportion of diabasic and amygdaloidal boulders are all of porphyritic nature but quite variable in molecular structure. A large portion of them consists of a reddish brown, compact, homogeneous, silico-feldspathic substance, with smooth, conchoidal fracture. Others inclose within the same aphanitic ground mass well formed, large crystals of feldspar, of red or whitish color; in still others, which are often more abundant than the others, the dark reddish colored, compact groundmass incloses, besides feldspar crystals, a great number of rounded transparent, colorless grains of quartz which, on fractures, gives a blackish reflex. Other pebbles have none of the amorphous ground mass; they consist of a granite-like agglomeration of interwoven red feldspar crystals, with scarcely any other component; or else this same crystalline, feldspathic rock mass contains copiously interspersed quartz grains, besides scattered blackish colored molecules which sometimes are recognizable as altered hornblende crystals or as biotite scales, but often are a shapeless, earthy-looking remnant of a decomposed mineral, not to be determined. These rocks could, with propriety, be classed with granite, but they are allied with the before mentioned porphyries by transitory forms which are not completely crystalline, but have a scanty interstitial ground mass analogous to the ground mass of the porphyritic kind.

"I have stated above that the copper occupies, in the conglomerate, the interstitial spaces between the pebbles and often takes the place of the previously existing arenaceous cement. Rarely the copper had a chance to enter the substance of the pebbles through capillary fissures imperceptible to the eyes before the pebble is fractured, but sometimes the same altering influences which remove the interstitial arenaceous material, replacing it by calcspar, epidote and copper, affected also the larger pebbles; they made them first porous and discolored and finally changed them into an epidotic mass permeated

with a spongy skeleton of copper in association with more or less calcspar. Such altered pebbles some of them as large as a man's head, quite frequently occur at the Calumet mine, and also sometimes in the conglomerate of the Albany and Boston mine. In some instances the copper has almost entirely replaced the material of such pebbles and forms solid, ponderous masses in the shape of the pebble, other times the change was not perfect, and the spongy copper skeleton inclosed within its cavities yet unaltered crystals of orthoclase and quartz grains enveloped by a mealy chloritic and epidotic crust.

"Prof. Pumpelly first gave notice of the occurrence of such copper masses in pebble form and suggested their paramorphic origin by replacement of the material of the decomposing porphyry pebbles.

"The conglomerate of the Calumet mines frequently incloses seams of a fine-grained, well laminated sandrock, exhibiting ripple marks on the surface of its layers, and locally such beds are richly impregnated with copper. Like in all the sandrocks of the Keweenaw group, the feldspar grains overbalance the quartzose grains in the rock mass. The hanging of the Calumet conglomerate is a dark colored, fine-grained diabase, which, like the above mentioned diabase belt in the Tamarack shaft, 500 feet below the surface, has a jointed structure, with the cleavage seams coated over with a soft, chlorite-like mineral in slickenside fashion, holding between themselves sheets of copper from the thickness of tissue paper to that of a knife blade and sometimes six or eight inches square; likewise are cloudy patches in the solid mass of the diabase disseminated with an abundance of scaly molecules of copper, but the miner considers the amount of metal too small to pay any attention to its collection. In association with the compact diabase in the hanging, amygdaloidal rock masses occur, whose amygdules formed of calcspar, laumonite, quartz and delessite, often contain a considerable amount of copper.

"I have previously mentioned that the Calumet conglomerate thins out and is almost destitute of copper in its extension south of the Osceola mine, and soon after entirely disappears. The same is the case in its extension northeast of the Calumet mine, on the Schoolcraft mining property, where extensive work has been done in this belt, but the large burrows of waste rock, in which no copper can be detected, show that the Calumet mine struck an extraordinary rich spot and that locally this belt is almost barren of the metal. The work in this conglomerate on the Schoolcraft mine was long since suspended, but on the Osceola amygdaloid belt, which likewise intersects the property, mining has been continued until late. Farther to the northeast the continuation of the Calumet conglomerate belt has been traced only for a short distance; it was found to be much narrower and poor in copper."

*Replacement of pebbles by copper.*—Dr. Pumpelly thus describes\* the replacement of conglomerate pebbles by chlorite and copper.

“Among the pebbles in the Calumet conglomerate there is a variety of quartz porphyry, with a brown, compact, almost jaspery matrix, which only glazes slightly before the blowpipe. In this paste there are numerous grains of dark quartz 1-20 to 1-4 inch in diameter, and often more frequent crystals of flesh-red feldspar, apparently orthoclase—1-10 to 7-10 inch in length.

“It not rarely happens, that in these flesh-red crystals there appear dirty green portions exhibiting the twin-striation of a triclinic variety. The feldspar is hard and brilliant, but is nevertheless no longer intact; under the glass the crystals appear cavernous, ten per cent or more of the substance being gone. This is the character of this porphyry in the freshest pebbles.

“I have before me a pebble four inches in diameter, broken through the middle. It was the same variety of porphyry I have just described—the same brown matrix, with the same grains of quartz, and the same large crystals of orthoclase, often enclosing crystals of triclinic feldspar. But this pebble carries on its face the history of an extreme change. In the interior, where it is freshest, the matrix, still of the same brown color, has become so soft as to be easily scratched with the point of a needle. The quartz grains are highly fissured, and the surfaces of the fissures are covered with a soft, light-green magnesian mineral. The feldspar, although it still resists the point of the steel needle, has generally lost its glance, and has an almost earthy fracture; it is lighter colored, and tends to spotted dirty-red and white. In places, specks of chlorite are visible in the holes in the altered feldspar, and the cleavage planes often glisten with flakes of copper. As we go farther from the middle of the specimen toward the original surface of the pebble, the matrix becomes much softer, though still with brown color and brown streak, and then changes to a soft, green, chloritic mineral, which whitens before the blowpipe, and fuses on the edges to a gray glass. A little farther from the center there is no longer a trace of the porphyry matrix; it is altered wholly to chlorite. The feldspar crystals are somewhat more altered here than they are in the middle of the pebble, but the quartz grains seem to have been in part replaced by chlorite. The change to chlorite is accompanied throughout by the presence of a large amount of copper. While in the interior of the pebble, the flakes of copper are confined to the cleavage planes of the feldspar, and the porphyry matrix exhibits scarcely a trace of the metal, the chlorite which has replaced the matrix contains in different parts of the specimen from 10 to 60 per cent, by weight, of copper.

\*Geological Survey, Michigan, Vol. I, Part II, pp. 37-38.



"In another pebble of the same porphyry, not only is the original matrix gone, but the usurping chlorite has been almost, if not wholly replaced by copper; and we have as the remarkable result a quartz-porphyry, whose crystals of feldspar and grains of quartz lie in a matrix of metallic copper. There is still a very small amount of chlorite present, but it seems to have come from the change of the feldspar crystals and quartz grains.

"In other pebbles of the same quartz-porphyry, containing, perhaps, less quartz, the alteration seems to have taken a somewhat different direction, or at least the result before us is different. In the interior of the pebble, the matrix is of a darker and dirtier brown than in the previous cases, which may be due to the presence of manganese in the alteration-product. Going from the middle, the brown color changes rather abruptly to a dirty greenish-gray; the material also becomes softer, but it is earthy, with an earthy odor, and gritty to the touch. The change seems here to be in the direction of kaolinization.

"The entire pebble is permeated with minute shining threads and plates of carbonate of lime. The lighter-colored portion contains considerable copper, while nearer the surface of the pebble it is largely replaced by that metal. Pebbles showing the various alterations described above are by no means rare. Many of them, from one inch to one foot in diameter, are found every day.

#### CENTRAL MINE VEIN.

*C. L. Lawton's description.*—Chas. L. Lawton says\* of the copper deposits at the Central mine, the mine being at the time, 1885, over 2,000 feet deep.

"It is in a fissure vein, crossing the formation south of the greenstone and extends vertically down, the bottom being 2,160 feet below the surface. It is a small mine, there is only one hoisting shaft—No. 2, and the copper bearing ground, which has a gradual pitch to the south, is now all south of the shaft—No. 2. The mine looks about the same as it has heretofore; there is no change whatever. The small conglomerate belt, which has been worked downward north of No. 4, has been abandoned, the belt no longer proving productive. The mining work is all confined to the copper shoot, which has, practically, afforded all the mineral that the mine has produced. The vein is continuous, sometimes only a ribbon of vein matter, which widens to eight feet to ten feet in width and contains the masses of copper; the most copper is found in the widest portions of the vein. When the vein matter is soft and spongy it is found to lack productiveness; a firm, hard vein yields the most copper.

\*Report Com. Min. Statistics, 1885, p. 221.



"The man engine is down to the 22d level. They open very little in advance of the stoping. In 1885 the total cubic fathoms of ground broken in the mine was 2,800, yielding 770 pounds of refined copper to the cubic fathom. Pretty rich ground, certainly."

*Production and variation in values with depth.*—Following are the statistics of copper production for each year of operation. In a general way the yield for successive years shows character of change in values with depths. The "slide" at the top of the Kearsarge conglomerate was encountered in sinking below the 29th level. Below the "slide" the vein was found to be 240 feet west and to be lean though well defined and carrying some copper.

## PRODUCTION OF CENTRAL MINE VEIN.

	Tons ore stamped.	Pounds refined copper produced.	Yield, per cent refined copper.
1859		241,622	
1860		114,197	
1861		248,742	
1862	7,514	484,764	
1863	9,946	619,268	
1864		901,292	
1865	17,552	1,099,242	3.13
1866	19,702	1,333,036	3.39
1867	17,064	1,244,441	3.64
1868	15,232	1,800,943	5.88
1869	17,688	1,807,801	5.11
1870	18,380	1,327,156	3.62
1871	21,646	1,432,662	3.30
1872	18,942	1,244,349	3.02
1873	15,903	1,503,117	4.72
1874	15,668	1,740,603	5.54
1875	17,118	1,466,952	4.28
1876	12,658	2,161,400	8.54
1877	14,119	1,995,609	7.06
1878	13,858	1,891,013	6.82
1879	12,478	1,799,495	7.21
1880	14,520	2,026,078	6.97
1881	20,549	1,418,465	3.45
1882	18,639	1,353,597	3.63
1883	18,146	1,268,556	3.49
1884	18,146	1,446,747	3.98
1885	17,812	2,157,408	6.05
1886		2,512,886	
1887		1,923,277	
1888		1,817,023	
1889		1,270,592	
1890		1,413,391	
1891		1,321,417	
1892		1,562,887	
1893		1,177,500	
1894		584,050	
1895		370,381	
1896		469,243	
1897		614,891	
1898		291,330	

## FOREST LODE.

The Forest lode is the productive amygdaloid of the Victoria mine in Ontonagon County. The ore occurs in a thick shattered bed of ophite, the copper being partly in amygdaloid and partly in dull altered trap. On some levels the lode is in three parts, referred to by Mr. Schacht, formerly engineer at the mine, as main, hanging and foot parts.

The hanging wall is characterized by remarkable "cups" or shallow circular depressions. These depressions are numerous and make the

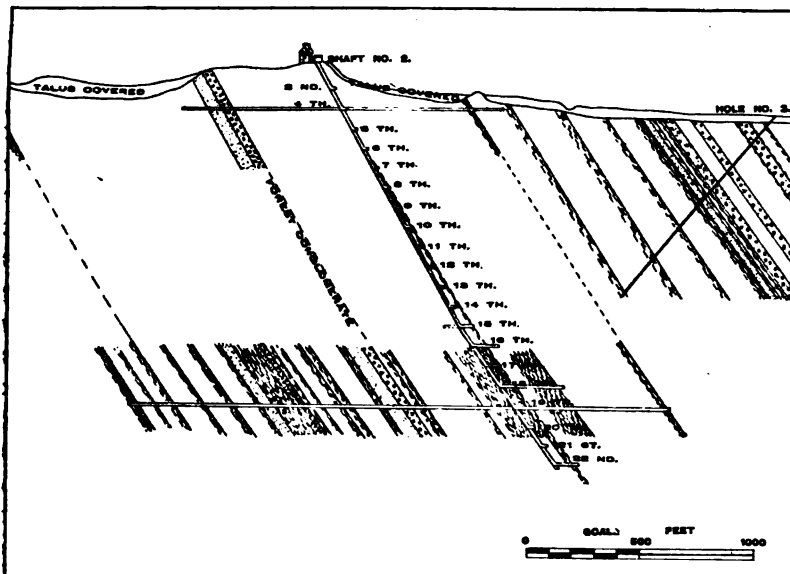


Figure 9. Geological section at Victoria mine, Forest lode (by George Hooper).

horizon an easily recognizable one. The depressions are not deep but the term "cup" is commonly used for them. In drifting, this "cup"-marked hanging has often served as a good guide in following the lode, though occasionally there is ore above instead of below it. The ore does not commonly extend to the cup-marked hanging, but is separated from it by one or two feet of dense trap known as the "cab." This "cab" has thin leaf copper in its numerous fractures, but seldom contains good values. It breaks off readily with the lode and thus adds a lot of waste which must be sorted out.

As a rule the ore bodies are small and separated by much poor ground. The most productive ground shows a pitch to the west. The bed dips

northwest at an angle varying from  $61^{\circ}$  at surface to  $55^{\circ}$  at the 15th level.

The ore mined in the past two years yielded between nine and ten pounds refined copper per ton. That this low grade material could be treated is due to the ownership of power rights on the Ontonagon River. Air is compressed by the fall of water, and mine and mill are operated at low cost.

#### HANCOCK LODES.

Several lodes have been opened up at the Hancock mine and others are now being tested. At No. 1 shaft there are three lodes known as No. 1, No. 2 and No. 3. At the new or No. 2 shaft there are three lodes which have been numbered No. 4, No. 5 and No. 6. Another lode has been found recently east of, that is below, No. 3.

*The No. 3 lode* is a chocolate brown amygdaloid spotted with numerous amygdules, many of which are chlorite. The rock is much altered, has a dull earthy appearance and is rather soft. The lode as mined averages about eight feet in thickness. It dips at about  $45^{\circ}$  to the northwest. The stopes are remarkably regular, the hanging wall being easily followed though frequently displaced for a few feet by faulting. Much of the copper in the ore is in the amygdules, and often enclosed in chlorite. During 1911 there was mined and treated from this lode 41,449 tons ore which yielded 18.21 pounds copper per ton. The quantity blocked out however, is not large.

*The No. 4 lode*, where cut in No. 2 shaft at a depth of 3,105 feet is a brownish gray amygdaloid. There are very numerous amygdules and many of them are quartz. Most of the other amygdules are calcite. Both quartz and calcite are often greenish in appearance owing to the presence of chlorite scales and occasional epidote grains. Many of the fracture faces of the rock are coated with quartz and calcite. On some there are fine scales of copper. Most of the copper is in the amygdules with the calcite and quartz; but some is in grains scattered through the matrix of the rock and some in seams of calcite and quartz. The lode where cut showed a thickness of seven or eight feet of good ore.

The No. 4 lode where opened by crosscut at the 34th level has quite a different appearance from that in the shaft. In the crosscut there is a thick bed of coarsely grained red colored trap which at some distance from the top shows an altered zone, of greenish color, containing much copper. This altered zone shows numerous light colored veins, many of which run about parallel to the bedding. The veins show some calcite and quartz; but much of the vein material is prehnite. The rock enclosing the veins has evidently been much altered and is impregnated with secondary quartz. In the veins and in the altered

rock native copper occurs in numerous forms, part coarse and heavy, part fine and part mere scales coating fracture surfaces.

*Footwall trap.*—Microscopic examination of specimens taken from the red trap below the lode show feldspar particles which are much altered, dull and red stained. The secondary aggregate is partly sericite and shows occasional grains of epidote. In some cases grains of native copper occur in the altered feldspar. The green chloritic mineral is partly ordinary chlorite showing pale green absorption

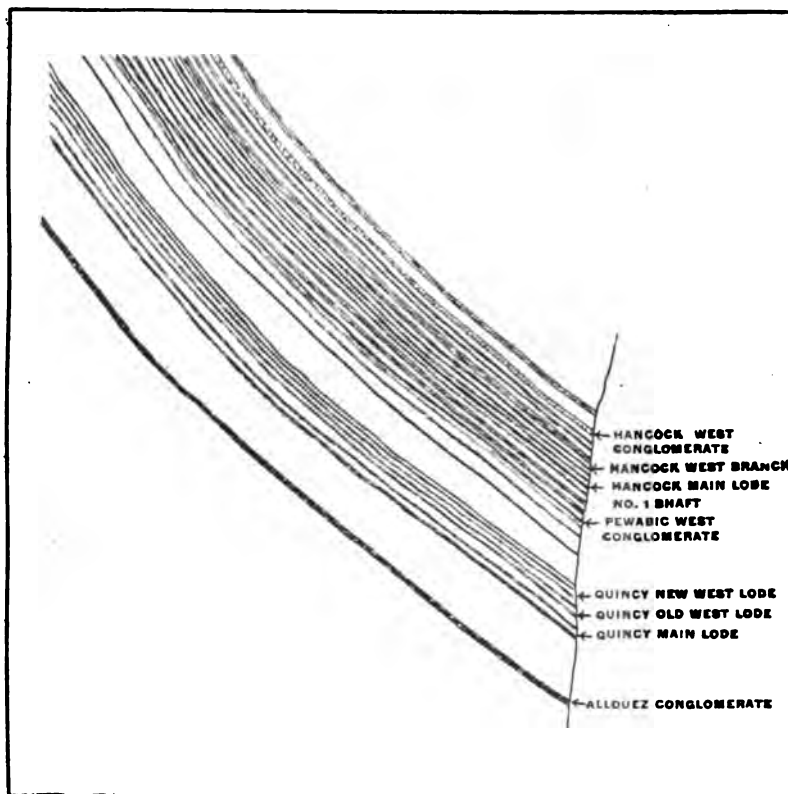


Figure 10. Section across Pewabic and Hancock lodes (by J. L. Harris).

colors and very low interference colors, but part of it is better crystallized and shows bright interference colors like delessite. Epidote occurs in distinctly colored and pleochroic yellowish grains. Magnetite occurs partly in large grains and partly as aggregates of very small grains. Some of the black iron ore has skeletal form of ilmenite and is surrounded by white opaque substance like leucoxene. Quartz occurs with the patches of green minerals and also in several crooked veinlets.

Some copper occurs in the quartz but more of it in the other minerals on either side of the quartz veinlets. Throughout the rock there is much red semi-opaque material that is probably iron oxide. It occurs abundantly around the black grains and more finely disseminated through the feldspars, giving them their red color.

*The lode.*—The lode is a decidedly green colored chloritic altered portion of the red trap, containing numerous thin light colored veins which are largely prehnite and calcite. In places there are numerous large grains of quartz and calcite scattered irregularly. Copper occurs as jagged grains scattered through the rock, as a constituent of the veins and as thin films in minor services in the rock.

Microscopic examination shows the rock to be composed largely of chlorite, delessite, epidote, rust stained altered feldspar, prehnite and iron oxides. Several black grains show a white alteration product and are probably titaniferous. Red oxide also occurs abundantly with the black oxide and as finely disseminated powder in the feldspar. Coarse clear quartz occurs in scattered particles, often with delessite crystals. In some specimens quartz encloses numerous delessite crystals; in others quartz is surrounded by delessite. A calcite veinlet runs through a broken plagioclase crystal.

*Occurrence of the copper.*—Copper occurs chiefly in the prehnite, being finely disseminated in threads and grains in fine granular aggregates of radiating crystals of that mineral. In a vein in the rock, copper occurs chiefly in prehnite, but also in or with a blue-black metallic mineral or with epidote. The mode of intergrowth seems to indicate that the copper has grown between grains of these minerals, penetrating cracks in and partly enclosing them. Between the rock and vein proper is a very thin zone that is a dull semi-opaque aggregate containing numerous very small grains of copper. Between crossed nicols the aggregate shows low gray interference colors with a few bright spots and some almost isotropic brownish areas. This zone probably has originated by replacement by vein material while the vein proper is a simple fissure filling.

One specimen shows very abundant quartz, part of which seems to have taken the place of large feldspar crystals. The quartz includes grains of epidote and copper and crystals of delessite. Some small copper grains are wholly enclosed by an epidote grain. Some quartz is peculiarly intergrown with a brownish pyroxene. Much copper is intergrown with a black metallic mineral (magnetite?) which occurs in long rods penetrating the other minerals.

*Prehnite veins.*—In the red trap there occur several prehnite veins carrying copper. The veins exposed in the crosscut are roughly parallel to the lode. A specimen of one of these veins examined microscopically,

shows the wall rock to change suddenly from the coarsely crystalline trap described above to a finely granular semi-opaque aggregate of greenish gray particles spotted with small grains of black and red iron oxides. A vein one-half inch thick shows clear colorless prehnite enclosing large and small, ragged and regular grains of copper. Part of the prehnite is a very fine granular aggregate from which radiate large crystals. The granular aggregate contains much fine copper while the clear coarsely crystalline prehnite contains few but much larger grains of copper. While microscopic examination shows that there has been some change in the wall rock at the immediate contact, the vein is in reality very distinctly marked off from the rock and to the naked eye appears as a simple filling in a fissure in the coarse trap. The reaction with the wall rock has been comparatively slight.

One section showing a prehnite vein enclosed by wall rock has the prehnite crystallized in large plates and grown out at right angles to the walls. The prehnite, encloses numerous coarse grains of copper in the middle portion and fine grains at the edge. Between rock and clear prehnite is a zone of semi-opaque granular prehnite containing numerous grains and strings of copper. In the midst of this semi-opaque aggregate are several clear grains of calcite.

#### INDIANA LODE.

This is a deposit located by diamond drilling on the Indiana property in Ontonagon County. Little is yet known of the extent of the deposit, but as several rich cores were obtained a shaft has been sunk 1,500 feet to permit of its investigation.

The lode is peculiar in that the copper occurs in felsite. Previously these light colored siliceous rocks had not been known to contain copper and the developments here are consequently of more than ordinary interest. The felsite from which the richest copper bearing cores were obtained is a very dense rock of light color. Generally it shows reddish tones, but in places it is pale yellowish-green from abundance of epidote. Much of it has a pale flesh color. In places the felsite is fairly fresh looking, but frequently it shows signs of much alteration. Calcite and epidote are abundant in the copper bearing portions. In places the rock is finely brecciated, the fragments being cemented with calcite. In practically all the drill cores there are very numerous joints and fractures and the mine openings thus far made show the same character. The rock is hard to drill and breaks up into very small pieces when blasted.

In a short drift at the 600 foot level at the Indiana mine copper was found at the bottom of a felsite mass at the contact with a soft, dull

brown colored melaphyre. Several masses of copper were found in the felsite, which at the contact is very much altered and contains abundant calcite.

Near the bottom of a second mass of felsite the shaft went through 30 feet of green stained felsite said to assay 22 pounds copper to the ton in the form of carbonate of copper. The carbonate, with some silicate, occurs as minute veinlets and patches in the dense felsite.

#### ISLE ROYALE LODE.

*General character.*—The Isle Royale lode is an amygdaloid worked extensively at the Isle Royale mine. What is supposed to be a con-

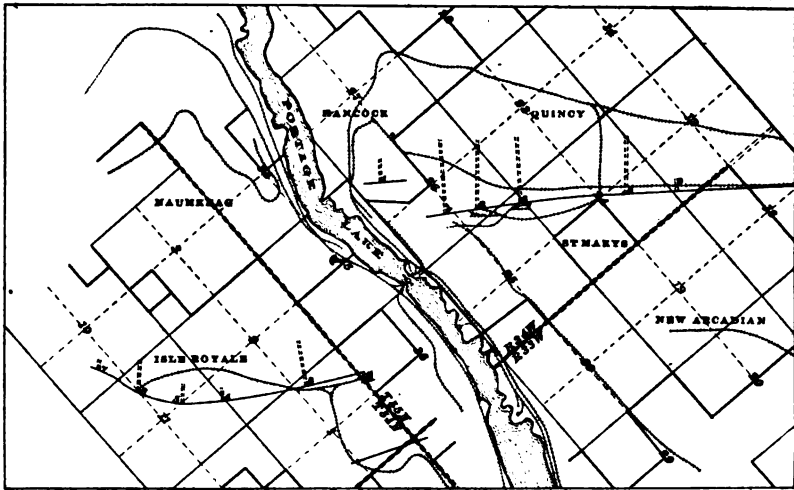


Figure 11. Map showing mines on Isle Royale and Quincy lodes.

tinuation of the lode was unsuccessfully opened up at several points by the Arcadian Mining Company north of Portage Lake. Further south the Winona is, in Dr. Lane's opinion, on the same lode.

At the Isle Royale mine the lode has commonly a gray, greenish or brownish ground mass which is rather distinctly though finely grained. In this are scattered amygdules composed of many species of minerals. Common among these are calcite, quartz, epidote, chlorite, prehnite and laumontite. Cracks in the rock have in most cases been filled with chlorite, laumontite or thompsonite. Much of the ore is spotted green with chlorite and epidote. The rock is fairly hard, but not so hard as the Kearsarge.

The rock has the composition of an olivine diabase. It is somewhat

mottled like the ophites, but contains a rather high percentage of feldspar. Dr. Lane calls it feldspathic-ophite.

The ore thus far mined is low grade, but better results are being obtained now than in former years and the copper is being extracted at a good profit. For the years 1908 to 1911, the yield was 13.8, 14.3, 14.5, 16.5 pounds refined copper per ton. It was estimated in 1911 that the mine would produce 435,600,000 pounds of copper from ore averaging 14 pounds per ton. Mr. J. R. Finlay, for the State Tax Commission in 1911 estimated that it would produce 112,000,000 pounds copper from above the 4,000 foot level.

At the northern end of the Isle Royale property the lode strikes S. 38° W. and dips to the N. W. at an angle of 58°. Towards the south the lode curves westward to S. 58° W. Above the lode there is a similar deposit known as the Grand Portage. This has been mined for short distances at the old workings and is now being opened up again by crosscuts from the main workings. Where recently opened up at a point 700 feet north of No. 2 shaft at the 29th level the Grand Portage was cut at a distance of 125 feet from the Isle Royale lode. It proved to be 62 feet wide with good ore on hanging and foot sides separated by lean ground.

In the Isle Royale the copper is more irregularly distributed than in most of the other productive lodes, occurring in patches of various shapes separated by lean or barren ground. The lode is therefore commonly referred to as "bunchy."

*T. Macfarlane's description.*—Thos. Macfarlane in 1866 said of the Grand Portage lode. "About 260 feet west of the 'Isle Royale vein' occurs the bed upon which the Grand Portage mine is situated. The color of the matrix is light green, thus differing greatly from the beds hitherto described (Pewabic and South Pewabic). It has an uneven earthy fracture, and is uncrystalline, with small white spots here and there through it. It is fusible and gives water when heated in a glass tube. The amygdules are all of a dark green color, and frequently consist exclusively of delessite. Quite as frequently, however, they consist of that mineral with a kernel of quartz, or much more rarely, of calcspar. The copper is found oftener in the amygdules than in the matrix. As in other beds, larger aggregations of crystalline minerals occur, in which quartz generally preponderates, associated with calcspar, prehnite and native copper. Specks of native silver sometimes occur in this veinstone. The strike of the bed is N. 40° E. and the dip 52° north-westward."





## KEARSARGE LODE.

*General character.*—The Kearsarge lode is the copper-bearing amygdaloidal upper portion of a bed of porphyritic melaphyre. Near the lode the bed is commonly a dark gray or brownish rock with large phenocrysts of feldspar, usually labradorite. This rock is commonly called by Dr. Lane and others, a labradorite porphyrite. Its porphyritic character is very pronounced wherever the lode has been opened, and it has served as a good horizon marker. The lower part of the bed shows numerous porphyritic crystals in a ground mass which has an ordinary ophite texture.

The lode itself is commonly a brownish amygdaloid showing numerous and large amygdules of calcite, quartz, red feldspar and green epidote in a dull, dense and fairly soft ground mass. In places the lode is greenish in color, containing much epidote and quartz, and is then quite hard. Some copper occurs in amygdules and may be a simple filling, but most of it is in irregular forms and has evidently replaced the rock.

As mined, the Kearsarge appears to be a remarkably uniform lode about 10 to 14 feet thick. The openings however, often give an incorrect idea of the distribution of the copper, as it is by no means so regular as the stope maps indicate. Compared with some of the other lodes, the Kearsarge is a very uniform bed and has, on some properties, been mined continuously for practically the same thickness from level to level. It is none the less true, however, that the lode varies considerably in thickness and the regularity of opening frequently indicates simply that the ore has not been always followed as closely as it might have been. In some places the openings are in barren rock and in others the full thickness of ore has not been broken. There are many and often very good reasons for this method of mining. It is mentioned here in order to call attention to the fact that the copper is much more irregularly distributed than some of the mine openings indicate. During the year 1912 at the South Kearsarge mine about 300,000 tons of ore was mined from deposits in the footwall and the company's president says in his report—"This rock (ore) consisted in part of vein matter which extended back into the footwall, and in part of foot trap which was found to contain copper. This rock can be mined cheaply, and it is hoped that a large part of the old stopes can be worked over in this way." It is not thought that all the mines on the lode have left as much ore in the foot as has the South Kearsarge, but it is frequently found in cleaning stopes of all broken ore that much copper has been left in irregular deposits in the foot. When this is broken out the Kearsarge will probably be found to more closely re-

semble the other amygdaloid lodes, though still by far the most regular and continuous amygdaloid.

*Extent of lode.*—The Kearsarge lode has been traced by mining operations, test pits and drill holes for a remarkable length. Dr. Lane says\* of its character:

“For the 32 miles that the Kearsarge lode has been followed the large phenocrysts persist, sharply distinct from the ground mass and from each other, but very little agglomerated, \* \* \*. The porphyritic trap which is the foot of the Kearsarge lode is an ophite, but the mottling does not show close to the margin. \* \* \* It is in some places one heavy bed 100 to over 200 feet thick. On top of this will be the well marked cupriferous amygdaloid which is the Kearsarge lode and then there will be no difficulty in identification. But this is not everywhere so. In places it will be broken up into successive gushes, each with its own amygdaloid and decrease of grain due to cooling. Besides this there may be irregular streaks of amygdaloid in the bottom of the trap. \* \* \* At the Cliff mine the distance from the Kearsarge to the Wolverine sandstone was about 90 feet and the Kearsarge foot was thick and characteristic.” At the Ojibway according to Dr. L. L. Hubbard, the trap is about 35 feet thick.

Dr. Lane states that the Kearsarge lode is clearly identifiable at the Mandan and well defined in the Manitou. It has been located at the Central and Miskwabik properties. It is being explored at the Ojibway and has been opened at the Gratiot and Seneca. It is being extensively mined at the Mohawk, Allouez, Ahmeek, North Kearsarge, Wolverine, South Kearsarge and Centennial mines. It is being opened up at one shaft on Calumet and Hecla and at one shaft on the Laurium property. At the La Salle two shafts have recently been put in shape for production. On the southern part of the La Salle property, according to Dr. Lane the Kearsarge shows a number of amygdaloids which are presumably overlapping gushes of the one flow. Dr. Hubbard, from observations at the Ojibway, believes that there was a marked geological internal between the foot-trap and later flows, although they are of similar character. Of its southern extension Dr. Lane says:† “The Kearsarge lode is, I think, also identifiable in the Rhode Island, Franklin and Arcadian sections. Beyond to the south I have not yet been able to identify it, which is the more strange since it is of good thickness at the Arcadian and it ought to be exposed somewhere between Houghton and Hurontown where I have made careful search at its horizon without identifying the peculiar and characteristic trap, though exposures are frequent.”

\*Michigan Geological Survey, 1909, pp. 314-315, Pub. 6.  
†Pub. 6, Michigan Geological Survey, 1909, p. 327.

*Distribution of copper.*—To some extent the copper in the Kearsarge is distributed in courses or shoots, but the richer parts are as a rule of very irregular shape and better, though poorly, described as patches. Within these patches the copper is scattered in numerous smaller patches and streaks more or less separated by barren or low grade rock. Frequently the whole face of a stope shows no ore, but the rock is all broken to expose the ore beyond. At the Wolverine, which is a small property located on one of the richest portions of the Kearsarge lode, some of the stopes which were abandoned on account of the very poor showing on the face have been subsequently reopened and good ore found suddenly after cutting through a few feet of barren ground. It is frequently noticed that the ore contains more water than does the barren rock and in the openings it is regarded as a good sign when the face is wet. It is common experience to break into good ore close to such a face. Captain Pollard stated that in poor ground a wet drift has proven a good indication of good ore above the drift.

*Parallel lodes.*—Above and below the Kearsarge, there are other amygdaloids which carry some copper. These have been opened in a few cases by crosscuts from the main lode and have yielded a little copper but have, as a rule, not yet proven rich enough to pay for mining.

*Masses.*—The Kearsarge lode has yielded considerable mass copper, but the masses are not commonly over a few tons in weight. At the Wolverine, according to Captain Pollard, masses of two or three tons have been not infrequently mined, but none are met with so large as to require cutting. At the Mohawk and Ahmeek, as already stated, considerably larger masses have been encountered and cut up, but most of these were from fissure veins crossing the lode and not from the lode proper.

*Two Lodes at North Kearsarge.*—From the early reports it appears that in places at the North Kearsarge mine there are two lodes and numerous displacements were encountered.

Supt. John Daniell in his report on the operations at North Kearsarge mine in 1887 says:

“Development has shown that overlying the lode on which we commenced operations and usually distant 30 to 40 feet from it, there is another bed of amygdaloid from three to four feet wide, occasionally wider. This last runs in nearly a straight course, while the main lode, very irregular in size, takes a very circuitous course, sometimes approaching the west lode very closely, and again leaving a well-defined trap between. At more than one point we have found in cross-cutting from one bed to the other, that the intervening material is wholly

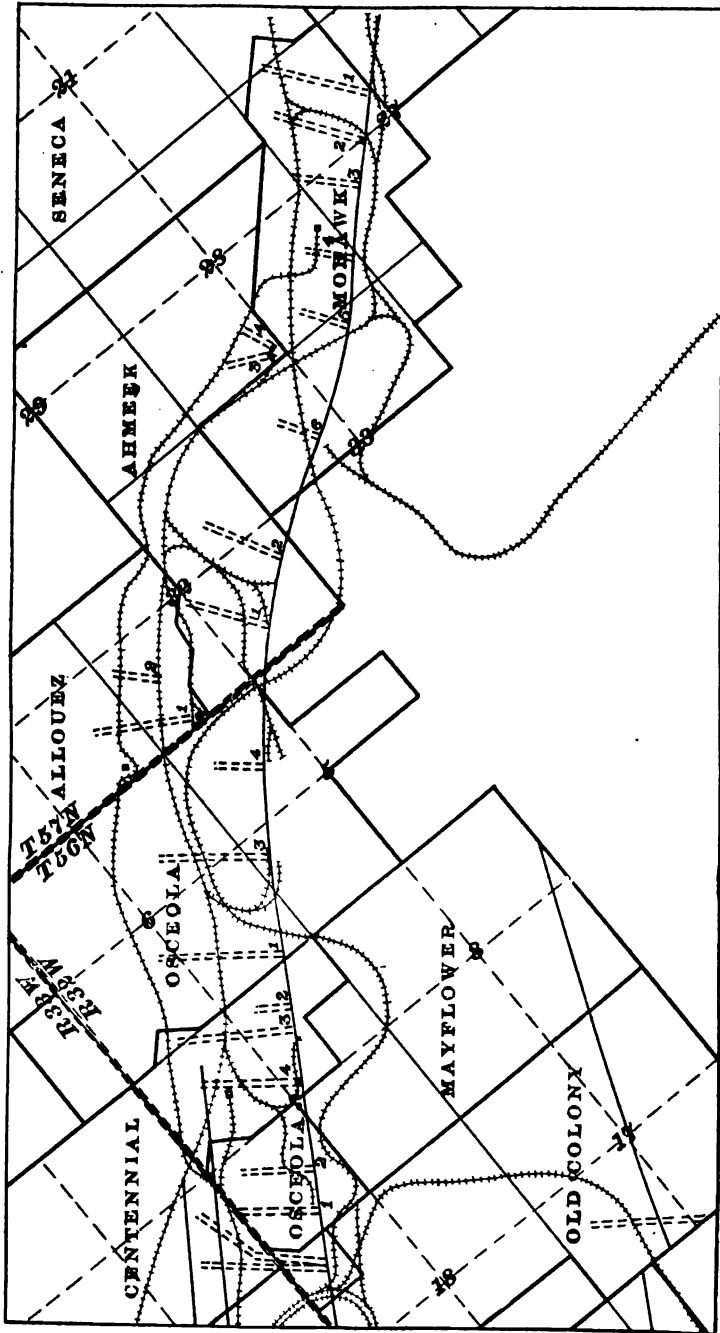


Figure 13. Map showing location of chief producing mines on Kearsarge lode.

amygdaloid, leading to the inference that both should be taken as one lode. At 5th level, No. 1 shaft, this is especially the case, but I cannot say that I am settled in opinion as to its correctness. Should this prove to be so, our chances of finding heavy deposits of copper in depth would be good. We look to early developments at 6th level to throw light on the question."

Supt. John Daniell says\* further in his 1888 report:

"From all we see during the past year there is no doubt but that the two amygdaloids referred to in last report are separate lodes, each continuing its course. The eastern one, on which most of our work is done, continues as irregular in course in the deeper levels as was before noted. The number of crossings and faults that we encounter, which invariably throw the lode, are in excess of anything seen in the district, and have much to do with the disturbed character of the ground we meet with. The influence of some of these should grow less as we get deeper."

Dr. Hubbard has observed that at the Ojibway mine there are two lodes, very much as above described; but with a probable modification as described in his paper before the L. S. Mining Institute, Houghton, 1912.

*C. Rominger's description.*—C. Rominger says† of the lode where it was opened at the Wolverine mine:

"This belt is unusually rich in copper. It is a dark purplish brown rock, with dull earthy fracture, harder or softer, much shattered into fragments, which are recemented into seams of calcspar and of orthoclase in association with quartz, epidote and delessite. The amygdules are filled with laumonite, epidote, delessite and calcspar, usually several of them associated; in some parts of the rock the amygdules consist nearly all of a dark green amorphous serpentine-like mineral. Much of the amygdaloidal belt is transformed into a light green porous epidote rock, which principally carries the copper in ponderous hackly masses, so called barrel-copper. Near the surface the copper is much oxidized, coated over with red oxide, malachite and axurite. The same amygdaloid belt is laid open by numerous test-pits in the adjoining Kearsarge property.

"The foot-wall of the amygdaloid is a coarsely crystalline, dark colored diabase belt, about 100 feet wide."

In 1911 Mr. J. R. Finlay estimated the future production of the five leading mines on the Kearsarge lode would be 63,600,000 tons ore containing 986,000,000 pounds copper.

\*Rep. Con. Min. Stat. Mich., 1888, p. 74.

†Vol. V, p. 118, Geol. Sur. Mich.

## LAKE LODE.

*General character.*—The Lake lode is a wide amygdaloid opened at the Lake mine in Ontonagon County. Where first found and developed it has a strike of nearly due north, but subsequent development has proved that it curves to the west and near the South Lake boundary it strikes almost due west. Diamond drill holes on the latter property indicate that it there also strikes westerly and dips to the south.

At the No. 1 shaft of the Lake mine the lode dips to the west at an angle of about  $34^{\circ}$ . The South Lake drill cores, as interpreted by Dr. Hubbard, indicate the dip there to be southward at an angle of about  $55^{\circ}$ .

The general strike of beds in the properties further west is northeast and the dip northwest. It is probable that the discordance in structure has been partly brought about by extensive faulting along a zone traversing the South Lake property. One of the drill holes traversed broken ground here and this is possibly the location of a fault, or more likely a series of faults

The lode is a brown amygdaloid spotted with amygdules of chlorite, calcite and other minerals. The ground mass is poorly crystalline, but deeper in the bed the rock has the characters typical of ophites. The mottling is fairly distinct on the footwall, which is an ophite spotted with dark green chlorite giving it a pseudo-amygdaloidal character.

The copper is irregularly distributed along the lode, rich and wide portions alternating with stretches of poor ground. Some of the richer portions have been cut out for a width of 40 to 60 feet and should yield much good ore. The value of the lower grade portions is not yet very definitely known as the amount of stoping is as yet considerable.

*East lode.*—About 100 feet east of the Lake lode there is another copper bearing amygdaloid known as the East lode. This is narrow, often only four or five feet thick, but is in places rich and occasionally there is a thickness of 10 feet of good ore. It is commonly greenish in color, partly from epidote but chiefly from abundance of a dull earthy green substance or green earth, and chlorite. The east lode follows the curves of the main lode, thus indicating that the structure as shown by the mine openings holds for a considerable thickness.

The Lake lode is fairly easily treated. It is soft and yields copper of good quality.

## MASS MINE LODES.

At the Mass mine there are four parallel lodes a short distance apart which have been worked at various times. These are, in ascending order the Evergreen, Ogima, Butler and Knowlton. The Butler

has recently been extensively opened and is the chief producer. The Evergreen ranks second as a producer. The Ogima and Knowlton are not being worked at present.

The *Evergreen lode* is a greenish amygdaloid which contains copper in irregularly distributed deposits. The ore is often rich and masses are common in the lode, but as a rule there is much barren rock between the good portions. Continuous stopes of any considerable size are uncommon. It has yielded much copper, but mostly from "bunches" or "pockets."

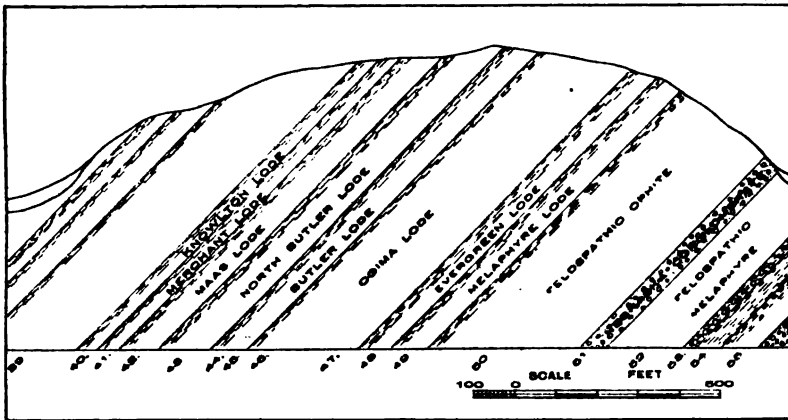


Figure 14. Cross section showing relationship of Butler, Mass, Ogima and Evergreen lodes at Mass mine (after Lane).

The *Butler lode* is an amygdaloid of peculiar reddish color, having abundant crystals of red feldspar, along with the more common minerals in the amygdules. The lode has been traced and opened up at intervals for several miles in Ontonagon County. It was mined by several of the old companies; but at present only at the Mass mine. The Butler is a wide bed containing ore at several horizons. At the Mass mine the bed is almost 350 feet wide with ore on the foot and hanging and in some places near the middle. The foot-wall lode is the main ore body and is known as the "Butler Vein." It averages about 10 feet but widens out in places to 30 feet. Frequently ore is followed up in irregular deposits in the hanging and in parts of the mine there are branches which have been followed and found to connect again with the main lode at some distance along the level or up in the stope. In other cases ore makes down into the foot and gives copper ground continuously down into the Ogima lode. Where the two lodes are close together, wide deposits of good ore have been mined, the copper continuing from one lode to the other. In some cases in following copper



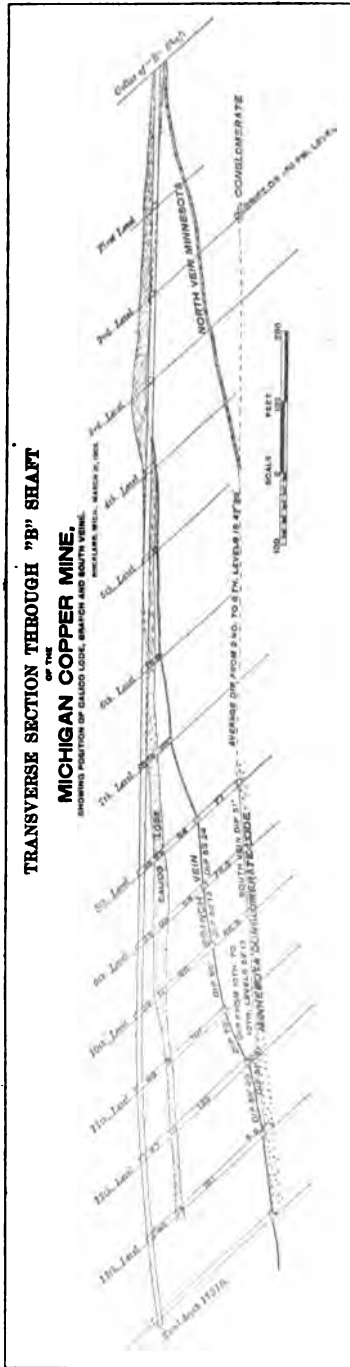


Figure 15.

without reference to character of the lode the miners have run in continuous good ore from the Butler into the Ogima lode.

*The Ogima lode* is comparatively dense and shows only occasional amygdules and is frequently referred to as a "trap" lode. It is a fine grained gray melaphyre spotted with epidote and chlorite. The copper occurs commonly in small grains or "shots" and masses are rarely found. Much of the lode seems dense and poor, but in places it is well mineralized and may in the future be profitably worked.

*The Knowlton lode* is a reddish amygdaloid resembling the Butler. Some large stopes were made in it years ago, but it is at present not a productive lode.

#### MICHIGAN MINE LODES.

At the Michigan mine several lodes have been worked. The chief producer was the Minesota vein elsewhere described but ore has also been taken from other veins and amygdaloids in its vicinity. The Branch and Contact veins and the Calico, North and South amygdaloids have contributed to the output. Some exploratory work has also been done on the Evergreen series of lodes now being worked further east at the Mass mine.

At the Michigan there has evidently been much fissuring. The main line of fracturing was along the bedding planes instead of across them as in Keweenaw County. From these main fissures, others of minor importance cut across the formation and in the mine these cross fissures were often found to contain ore. Some account of these is given under the heading Minesota lode.

#### MINESOTA LODE.

*General character.*—The Minesota lode is a vein rather than a bed. It strikes with the formation in which it occurs, but dips somewhat steeper and so gradually changes in horizon. The vein material is of greenish color, being chiefly made up of epidote, quartz and calcite. Copper occurs more largely in masses than it does in most of the lodes. Comparatively little of the copper produced was from stamp rock. The lode has been pretty well worked out and abandoned by the mining companies. For the past few years tributors have been doing some mining in the upper levels at the Michigan mine, especially on what is known as the Branch vein.

The first workings were on what is known as the "Minesota" vein which lies immediately above a bed of conglomerate known as the "Minesota conglomerate." From this the "Branch vein" diverges at a small angle cutting the upper beds, including an amygdaloid known as the Calico lode. Owing to the slight divergence between

the vein and the Calico amygdaloid, the latter was the wall rock for a considerable distance and much of it was well mineralized and was profitably worked.

*C. L. Lawton's description.*—Chas. L. Lawton describing the deposit worked at the National mine says:\*

“The old mine is in a vein of contact that outcrops along the side of the southerly slope of the bluff, and which is contained between an underlying conglomerate and the overlying trap; the gangue of this vein is chiefly quartz, calc-spar and epidote, and has afforded, in times past, many fine specimens of all these minerals. It is usually known as the conglomerate vein, and sometimes it is incorrectly supposed that the conglomerate yielded the copper; but the copper was invariably

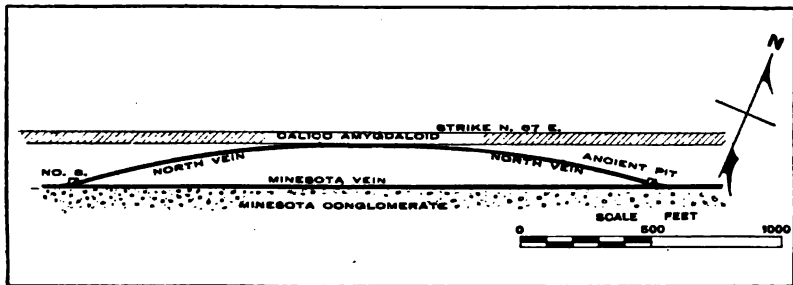


Figure 16. Ground plan sketch showing the relative position of Minnesota conglomerate, Minnesota vein, north vein of Minnesota, and the calico amygdaloid.

the product of the vein. Sometimes the vein matter penetrated into the conglomerate, and masses of copper were obtained in such places; but not otherwise was copper found in the conglomerate. A prominent feature of the old mine was what was called the counter vein, a branch of the main vein, which extended diagonally, northwesterly, across the formation to intersect an amygdaloid belt that is situated 140 feet north of the conglomerate and runs parallel with it. This counter vein was also productive in copper, and especially so along its lines of intersection with the main vein and with the amygdaloid. In the vicinity of these lines of intersection, in the upper levels, were found the richest portions of the mine.”

In another report Mr. Lawton gives further description of the lode as opened at the National and Minnesota mines. He says:†

“The belts embraced within the limits of the workings of these mines are first, sandstone 40 feet wide; overlying this is a bed of conglomerate 30 or 40 feet wide, and upon this is a belt of trap 140 feet in width; but below the conglomerate and this trap is a belt of vein matter

\*Report Com. Min. Stat., 1888, p. 20.

†Report Com. Min. Stat. Mich., 1885, p. 201.

—generally assumed to be a contact vein—having a variable width of from perhaps six feet to 15 feet wide. Overlying the trap is a belt of amygdaloid varying also from six feet to upwards in width, sometimes also making out into large pockets; this was called the north vein and was never much worked, as it is a stamp lode, though affording some mass copper and barrel work. So far as opened by the old company in former years it afforded some rich ground, about three feet wide along the foot wall, and thence to the hanging it was lean. Some of this foot wall part of the lode was very rich; 300 tons of it were stamped which yielded three per cent copper; a larger portion, which included the body of the lode, yielded a little under two per cent; these facts I got from Capt. Chynoweth who was an officer of the National at the mine for 25 years.

“Running through the trap from the conglomerate to the north vein are frequent fissures and in these and in their vicinity in the main vein the bulk of the copper was found. Especially was this true of a diagonal fissure that extends through the trap to the amygdaloid west of No. 2 shaft. This was found to be very rich in copper in all the levels; as it dips at a less angle than the formation it tends to intersect the conglomerate vein and in this line of intersection, it is probable, much copper may be found; the work now is towards reaching this result. This fissure was first found by a crosscut, at right angles to the formation, and was thought to be an independent vein, but upon following it in both directions it intersected the main lodes; other fissures, of less importance, also yielded copper in considerable quantity. The conglomerate does not hold any copper; masses of copper were sometimes found in the conglomerate where an opening or fissure in the conglomerate had become filled with vein matter. One of these openings extended through the conglomerate to the sandstone and was very productive in copper, in fact was almost completely filled with pure metal. It was in a fissure in the conglomerate that a 500-ton mass of pure copper was found in 1857, probably the largest native mass of copper ever discovered.”

“The property (Minesota) is crossed by the same belts heretofore described and the formation is the same as in the National. Seventy per cent of the product of the Minesota mine was mass copper, the remainder, small pieces—‘barrel work,’ with a very few per cent of stamp copper.

“It was a wonderful deposit. Sometimes the only work was to cut up the masses of pure metal and hoist them to the surface. In places the stopes were nearly all copper.

“The map of the mine in Report Com. Min. Stat. Mich., 1885, p.

206 shows only the workings on the south vein—the conglomerate vein—as in the National; but lying north of this, between it and the amygdaloid, was a fissure vein running also east and west, but finally terminating in a cross-fissure to the west and intersecting the conglomerate vein to the east. In this longitudinal fissure the mine was first opened and worked before the fact of the existence of the other lodes had been ascertained. The National Company began on the conglomerate vein, and when they found that they were not working in the same vein as the Minesota people, they cross-cutted to find it, and came into a diagonal vein, as previously described. This middle vein in the Minesota mine lies north of the blank space shown on the section of the mine between No. 4 and No. 10 shafts. It dipped at a less angle than the conglomerate vein, and finally intersected it in the line indicated as the margin of the blank space on the map. Along this line of intersection of the conglomerate and the middle vein was the most productive ground found in the mine.”

*G. D. Emmerson's report.*—The character of the ore mined is indicated by the description of Mr. Geo. D. Emmerson of conditions at the property in 1857. He says:\*

“It was against the established rule that a vein could lie between two kinds of rock so dissimilar as trap and conglomerate.” \* \* \*  
 “But they are finding immense masses of copper in the conglomerate under the vein. A few days ago this was showing in the most marked manner in several points. In the 20 fathom level, east of No. 5 shaft, in the south lode, the regular sheet of copper had been taken from the foot wall, and the yield at this point had been very great. The masses were from 12 to 18 inches thick. Strings of copper were cut off that seemed to branch into the conglomerate. These were followed and led immediately to very large masses, some of which were of the thickest copper ever before taken from the mine. One piece which was cut off presented a face of bright copper cut by the chisel three feet and nine inches in thickness. It was so thick that it could not be handled in the mine without again dividing longitudinally, or splitting. Thus the mass showed two flat surfaces, at right angles with each other, of bright copper cut by the chisel. This point in the mine has been extremely productive. Some 200 tons of large masses have been taken out of the conglomerate under the lode, besides the enormous yield of the vein itself overlying it. In one place the copper extended into the conglomerate as far as 16 feet south of the foot wall.

“An occurrence of copper in all respects similar is found to the west of No. 5 under the adit level. Besides the masses in the regular vein, which was also extremely rich at this point, they had taken only 40

\*Report of C. E. Wright, Com. Min. Statistics, Mich., 1880, pp. 75-76.

or 50 tons out of the conglomerate, the foot wall was perfect as in the other case, and strings leading into the conglomerate were quite small, and very slightly attached. But by trifling labor they uncovered a series of masses going up and down, with an eastward indication, for the height of 70 or 80 feet and going out of sight both above and below. It was at once apparent that they had something very valuable, but they had no conception of the immense thing which a few days' work disclosed. At one convenient point they broke away behind the copper so as to get in a sand blast of five or six kegs of powder. They stripped the mass further and again fired without result. Again they fired nine kegs of powder and the mass remained unmoved. Bucking the rock around for a considerable distance 18 kegs of powder were shot off without effect, and again, 22 kegs, and the copper entirely undisturbed at any point. After further clearing, 25 kegs were shot off under the copper, and it was thought with some effect. But a final blast of 30 kegs, or 750 pounds, was securely tamped beneath the mass and fired. As soon as the smoke cleared away, a mass of copper 45 feet long and three to five feet in thickness, apparently very pure and which will probably weigh 300 tons had been shot out and was ready for cutting up. The blast had torn the immense body from its bed without exhibiting a sign of breaking or bending in any place, so great was its thickness and strength. It was torn off from other masses which still remain in the solid rock. About 100 feet to the east from this is another large mass which several parties are exposing, and from present appearances, it may exceed in size the last named one. These are near the point of the great counter lode from which 300 to 400 tons of copper have been taken; and the ground in the vicinity has unquestionably yielded the greatest amount of mineral ever taken from the earth in the same space. Its occurrence has been in three distinct forms: 1. In the counter lode; 2, in the regular vein; and 3, in the conglomerate rock under the vein.

"At No. 2 shaft they are sinking below the 60 fathom level, and are experiencing great difficulty in getting through the copper which they encounter. It was feared that they would be compelled to turn the shaft entirely out of the vein to enable them to sink. There are 1,000 tons of copper in sight—much of it ready for cutting."

*Large masses.*—A further extract, dated March 7, 1857, says: "There is now in the Minesota mine, between the adit and the 10-fathom level, a single detached mass of apparently pure metallic copper, which is some 45 feet in length, and in the thickest part as much as eight or nine feet in thickness. It contains probably more than 500 tons of pure metal, and is worth, as it lies, more than \$150,000."

Mr. Wright further describes this mass as follows:

"This is believed to have been the largest complete mass of native copper ever discovered. The exact weight was not ascertained, but enough of it was weighed to ascertain that the total would not fall short of 500 tons. Its greatest length was 46 feet, and its greatest breadth,  $18\frac{1}{2}$  feet; greatest thickness,  $8\frac{1}{2}$  feet. The main width was  $12\frac{1}{4}$  feet, and the main thickness four feet. It took 20 men 15 months to remove it from out the rock. Some of the cut faces measured 16 square feet. The cutting up afforded 27 tons of copper chips."

(While the large mass described by Mr. Wright is often referred to as the largest mass mined, a still larger one of 520 tons is reported to have been taken out at the Phoenix mine. An enormous mass discovered recently at the Trimountain will probably prove still larger.)

The common occurrence of masses is illustrated by the following figures of production of the several classes of ore.

COPPER PRODUCTION OF MINESOTA MINE, 1857-1859.

	Mass copper.	Barrel copper.	Stamp copper.	Total product ore.	Per cent refined copper recovered.
1857.....	3,015,581	819,900	280,512	4,115,993	74.1
1858.....	2,429,980	903,871	333,352	3,667,212	70.1
1859.....	2,040,454	929,571	282,092	3,252,117	71

This does not show the character of the ore very faithfully as stamped rock was neglected while rich masses were plentiful. It serves however to indicate that the relative proportion of masses was much larger than in other lodes.

## NONESUCH LODE.

*General character.*—The Nonesuch lode is a cupriferous bed occurring in the Upper Keweenawan in Ontonagon County. The bed carries native copper and chalcocite in small particles filling spaces between and sometimes forming a coating on the sand grains. The rock is a rather coarse sediment varying from sandstone to conglomerate. Much of it is a medium grained, gray colored sandstone, in part fairly hard, but as a rule not strongly cemented. It is very easily drilled and broken, but the rather flat dip increases cost of handling ore in the stopes. At the White Pine mine the dip varies from  $18^{\circ}$  to  $35^{\circ}$ . At the Nonesuch it is steeper than at the White Pine.

*At Nonesuch mine.*—Until recently the most extensive workings on the lode were at the Nonesuch mine. Good ore was found, but considerable difficulty was experienced in concentrating it, on account of the fineness of the copper. This difficulty was overcome and the

lode was tested to determine the extent of the ore body and the grade of ore. It is stated that good values were found, but it was not proved that there was much ore available.

*At White Pine mine.*—During the past few years promising results have been obtained at the White Pine mine. Here two beds known as the “First lode” and “Second lode” have been opened and found to be well mineralized. The beds are gray sandstone like that at the Nonesuch mine and are in places heavily loaded with copper and chalcocite. The First or Upper lode is the better. The beds average about six feet in thickness, varying from four to six feet. They lie parallel and close together, being separated by about five feet of dark colored slate. The hanging wall bed of the Upper lode is a thick bed of similar black slate. The foot wall of the lower lode is red sandstone, which at a depth of about 40 feet below the lode contains numerous pebbles. This conglomerate phase is fairly persistent and forms a good horizon marker.

It has been found that the lodes are much faulted. In many cases these faults, of the normal type, have allowed blocks to drop in such a way as to increase the apparent dip. In one place faulting of this character has brought the upper lode almost exactly into line with the lower lode.

*R. D. Irving's description.*—Dr. R. D. Irving has described\* the ore bearing rock at the Nonesuch mine. He says: “At the Nonesuch mine, S. E.  $\frac{1}{4}$  Sec. 1, T. 51, R. 43 West, the shale is seen with a thickness of over 200 feet, trending N. 45° 50° E., and dipping S. E. 28°. Near the base of the shale is the sandstone seam, four feet thick, worked at the Nonesuch mine for its copper. This rock is a dark greenish-gray, fine-grained sandstone, which in the thin section is seen to be composed in some measure of basic detritus, along with porphyry detritus, and numerous single quartzes. The basic detritus appears in the shape of much decomposed red and green-stained particles, showing both feldspathic and augitic ingredients. A good deal of magnetite is present, and native copper is very abundant, for the most part clustered around the magnetite particles. In a few places secondary calcite lies between the grains. Beneath the copper-bearing sandstone there come a few feet of shale, also carrying some copper, and beneath this some two and a half feet of a light-gray sandstone, harder than usual, beneath which again is the great sandstone layer previously described.

“The seam just mentioned as occurring at this junction has been traced for a number of miles in the valley of Iron River, and is the one which has attracted so much attention in this region for the silver it contains. Under the microscope it is seen to differ from the Nonesuch

\*Monograph V. U. S. G. S., p. 221.





copper sandstone, and, indeed, from the rock of the shale belt generally, in that it contains some water-deposited (secondary) quartz between the grains, which consist, as usual, of mingled porphyry and basic detritus and quartz particles. Calcite has also been deposited more or less plentifully in the interstices of the grains, and in some sections is the only indurating material."

#### OSCEOLA LODE.

*General character.*—The Osceola is an amygdaloid which has been mined extensively by the Osceola, Calumet and Hecla and Tamarack mining companies. On these properties it has been worked for a length of over three miles, openings extending completely across the Calumet and Hecla property and over a mile south on the Osceola. Further north the lode has been explored by the Centennial and Wolverine companies, and further south by the La Salle company, but operations on these properties were unsuccessful.

The lode underlies and runs parallel to about 400 feet east of the Calumet conglomerate striking N. 33° E. and dipping at the surface at Calumet at an angle of 38°. The workings on C. and H. property are as yet comparatively shallow, but the lode has been opened at greater depth by crosscuts from the conglomerate lode, and has been worked at considerable depth by the Tamarack Mining Company. The deepest shafts in the lode itself are No. 5 and No. 6 Osceola which are respectively 4,623 feet and 4,592 feet deep. The deepest shaft on C. and H. property is 3,232 feet deep.

The lode is a brown amygdaloid spotted and streaked with calcite. Most of the amygdules are calcite. The ground mass is softer than that of most lodes, and has commonly a dull and almost earthy appearance. It is easily crushed by the steam stamps and wears the stamp shoes much less than does the ore from most of the other lodes. Below the lode the rock becomes more crystalline in character and shows the mottling typical of the ophites.

*Hanging and foot parts.*—The Osceola lode varies in width and is in places very wide. The ore comes from two horizons known as hanging and foot parts. The chief and most regularly shaped and continuous ore body is the upper part of the bed. This hanging wall lode averages about nine feet in thickness and is fairly persistent and well defined. Below it there is commonly dense brown melaphyre succeeded by more amygdaloid in which are irregularly shaped ore bodies. These foot wall deposits are often richer and thicker than the hanging wall ore bodies, but they are of more pockety character and do not persist so regularly with strike and dip. In some places foot and hanging

portions are continuous and there the lode is very wide, often 40 to 100 feet. More commonly there is 10 to 20 feet of so-called "vein trap" separating them. The amygdaloid encloses numerous lenticular masses of dense trap. Often a bar of trap runs across the amygdaloid and it has been frequently noticed that the rock on either side of such bars is unusually rich in copper. The copper in the lode shows up rather conspicuously and in good ore can be readily detected by the naked eye. A fairly satisfactory selection is made before breaking the ore and little sorting of broken rock is done underground. Some waste is sorted out at surface and with other poor rock sent down into the mine again to be used in filling stopes.

*Future production.*—In 1911 Mr. J. R. Finlay estimated the future yield of the Osceola lode on Calumet and Hecla property at 23,000,000 tons, yielding 330,000,000 pounds copper. There will also be a large output by the Osceola Mining Company and a small output by the Tamarack Company.

*C. Rominger's description.*—C. Rominger says\* of the Osceola amygdaloid:

"The Osceola amygdaloid belt is about 35 feet wide; it dips in conformity with the other strata at an angle of 40° to the northwest; its color is reddish brown, dull, earthy; part of it is soft, porous, other parts hard, compact; its amygdules are principally filled with calcspar, delessite, prehnite and epidote; sometimes also with quartz, datolite, etc. The copper in the rock is mostly found in a network of fissure seams traversing the amygdaloid belt in association with calcspar, prehnite, datolite, quartz and epidote, filling the interstices between these minerals in hackly masses of smaller or larger size; sometimes the copper is found in druse cavities in very perfect, but rather small crystals; the spar crystals of such druses usually are bright red colored, being penetrated with an abundance of minute scales of copper.

"The datolite, which in the Portage Lake mines occurs only in amorphous porcelain-like concretionary masses, is here found in large crystals of pale greenish milky color, but rarely obtainable with free ends, as the crystals are densely agglomerated and enveloped with calcspar and prehnite.

"The hanging of the Osceola is a dark, blackish colored, fine-grained diabase, which incloses in its linear fissures sheets of copper, and is locally throughout its entire mass impregnated with minute scales of copper. Thin sections exhibit a large proportion of olivine grains in its composition, besides the ordinary constituents, plagioclase, augite, magnetite and interstitial masses of the green chlorite or serpentine-like mineral, which likewise fills distant globular amygdules."

\*Geol. Survey of Michigan, Vol. V, pp. 110-111.

"In the hanging of the conglomerate belt at the Osceola location, a dark, fine-grained compact diabase belt occurs, which incloses irregular amygdaloidal rock masses rich in copper, most of it in coarser lumps—so called barrel work. They use the old shaft in the conglomerate belt to come to this rock belt and work it to advantage.

"The compact and the amygdaloidal rock are both olivine bearing; the copper is principally found in fissure seams associated with calcspar, prehnite and dark red orthoclase."

*C. L. Lawton's description.*—Chas. L. Lawton says\* of the Osceola lode as opened at the Osceola mine in 1885:

"The lode possesses every degree of irregularity, and there is so much dead ground that the mine has had to be very largely opened in order to secure the product that has annually been made and the work has been done in a most effectual and economical manner. The misfortune in the Osceola mine is that the best ground is in the north end; the levels in this end are constantly shortening as the mine deepens. This is due to the fact that the Calumet and Hecla joins it on the north, and that the line of division of the properties, up to which the workings closely reach, bears north, 39° east, while the dip of the mine averages about 39° northwesterly, thus the boundary cuts diagonally across the lode, shortening it on the Osceola and lengthening it on the C. and H. The reverse is the case at the south end of the property, where the company has plenty of room to extend, but unfortunately the ground has not proved as productive in that direction. However there are signs of improvement; the south end is certainly better in the bottom than it has been heretofore."

*At Tamarack mine.*—The amygdaloid was opened up at the Tamarack mine by crosscuts from No. 1 shaft. Supt. John Daniell says in his 1893 report.

"On the Osceola amygdaloid we have drifted south of No. 1 crosscut, 14th level, 231 feet. At 15th level we have drifted south 172.7 and north 18 feet. In quality it has been irregular, but showing copper enough to indicate that it will pay to work. At 14th level we have stoped 490 fathoms of ground, the lode averaging 11 feet wide and affording a good grade of stamp rock, with an occasional piece of barrel work."

\*Report Com. Min. Statistics, 1885, p. 246.

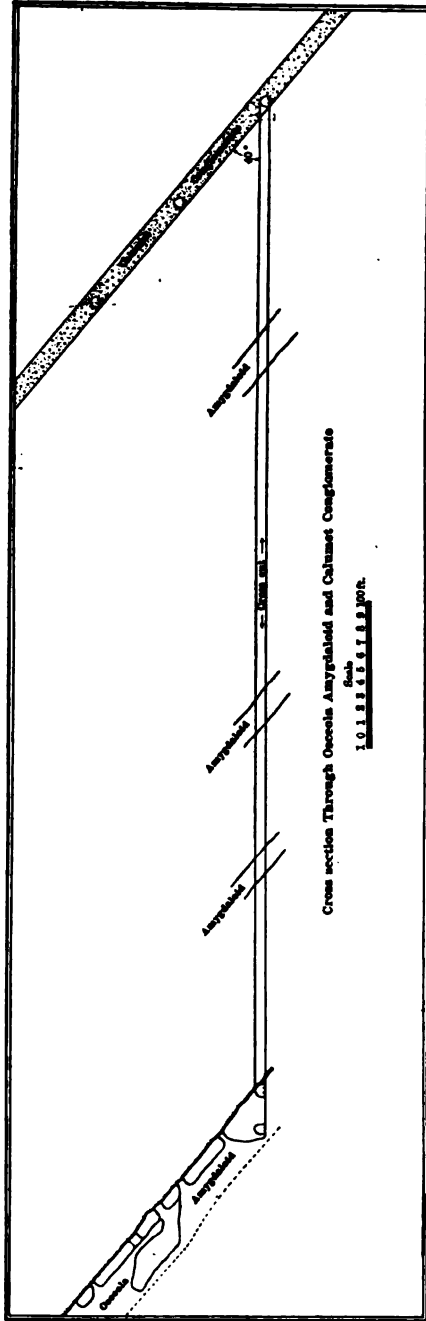


Figure 18.

*Chemical composition of Osceola lode.*—Dr. Lane has published in his recent monograph the following analysis furnished by Mr. J. B. Cooper, of slime overflows from the trough classifiers between stamp-heads and jigs treating Osceola amygdaloid ore.

Loss on ignition.....	7.89%
SiO <sub>2</sub> .....	41.31
Fe <sub>2</sub> O <sub>3</sub> .....	12.90
Al <sub>2</sub> O <sub>3</sub> (+ Trace TiO <sub>2</sub> ).....	22.46
CaO.....	11.08
MgO.....	4.07
Cl.....	0.11
SO <sub>2</sub> .....	Trace
Cu.....	0.14
Na <sub>2</sub> O and K <sub>2</sub> O.....	Not determined.
	99.96

#### PEWARIC LODE.

*General character.*—The Pewabic lodes are the copper-bearing amygdaloids mined at the Quincy and Franklin Junior mines, and now being opened up at the Hancock mine. At the Quincy there is a zone about 300 feet thick in which are several lodes. These vary considerably in relative productivity in different parts of the mine. There is commonly one lode that continues more regularly than the others for some distance and then becomes known as the “main” lode. As the workings are extended this main lode frequently becomes locally quite subordinate in importance to one of the “east” or “west” lodes. According to General Manager Lawton, the lode called the “main” lode at one shaft is not the same bed as that which is called the “main” lode at another shaft.

For the most part the lodes run nearly parallel to one another and are separated by trap. A large ore body in the “east” lode was opened by crosscuts about 60 feet in length from openings on the “main” lode. Often two lodes are separated by only a few feet of dull brown trap and occasionally two come together and then form wide bodies of ore that are in many cases richer than the narrow parts. At the Quincy mine there are in most places two lodes being worked and in several places three. In one part of the mine four lodes are being extracted.

The lodes are highly altered portions of dark gray feldspathic lavas, porphyrites, known locally as the “Ashbed” type. They occur at the same horizon as similar rocks at Eagle River where the term “Ashbed” was applied to the scoriaceous top of a flow and subsequently to a whole series of feldspathic lavas. The amygdaloid shows chlorite,

calcite, epidote, quartz, prehnite and native copper in a dark brown or gray ground mass. The trap is a fine but distinctly grained dark gray porphyrite, spotted with small particles of green chlorite.

*Occurrence of the copper.*—The copper occurs to some extent as a filling in cavities, but most of it has evidently replaced the rock, and forms irregularly defined masses, large and small. The larger masses are more abundant than in most of the lodes. While most of the copper is found in the main amygdaloidal parts of the bed, a large quantity is also mined from irregularly defined portions of the footwall trap. The lodes are crossed by a number of persistent calcite veins, but these are usually barren and in parts of the lode that are poor.

*The distribution of copper* in the lodes is very irregular and in stoping it is a common occurrence in fairly good ground to frequently expose a large face of very lean or barren rock. This is necessarily broken to get at the ore beyond and lowers the average yield per ton. Some of the waste, however, is sorted out underground and used in filling the stopes.

At the Quincy mine, the main lode is on the average about 10 feet thick, varying from three feet to 15 feet. The inclination, as with most of the lodes, becomes less with depth, being near the surface about  $54^{\circ}$  and in the lower workings, over a mile down on the slope, about  $40^{\circ}$ . In places in the northern part of the mine the dip at the low levels is about  $38^{\circ}$ .

At the Franklin Junior mine the lode being mined is about eight feet thick. Exploration has proven the existence here also of parallel lodes, but these have not yet been extensively opened. The yield at the Franklin Junior has been considerably lower than at the Quincy, but the recently opened lower levels show fairly good ore. The dip of the lode varies from  $49^{\circ}$  near surface to about  $43^{\circ}$  at the 32d level. At the Franklin there is a very characteristic hanging wall trap, unusually dark colored and dense.

The lodes strike N.  $30^{\circ}$  E. and at the Quincy are opened for a distance of about three miles. Between the northernmost Quincy shaft and the Franklin there is a long stretch of unknown ground which will doubtless be sometime explored. The Quincy first confined operations largely to one lode, but subsequently by exploratory crosscuts developed the others and has for years kept a diamond drill in operation probing foot and hanging walls.

#### Production.

The Pewabic lode had yielded at the Quincy in 1911 about 600,000,000 pounds of copper. In 1912 the Quincy mine produced 20,634,800 pounds and the Franklin Junior 1,710,651 pounds. If the yield per







ton proves satisfactory the latter mine will show a much larger production in a few years. At the Quincy the southern workings are nearing the boundary, but the central and northern parts of the property have a long future before them.

*Rich portion.*—The best large body of ore at the Quincy appears to have been a portion of the "East" lode about 1,800 feet long and 300 feet wide, pitching southward from the 25th level 800 feet north of No. 2 shaft to the 36th level 300 feet south of No. 4 shaft. During the period that this section was being mined the yield was over two per cent and in 1882 when much of the ore was coming from the 25th to the 30th level the yield was 3.13 per cent. The 25th and 26th levels north of No. 2 shaft were exceptionally rich. At the shaft the best ore was at the 30th level, and further south it was deeper.

*Present average.*—At present and for some years past the ore mined has averaged about 16 pounds per ton. The lower yield is due largely to the lode being much less rich, but partly also to the fact that improved mining methods make it possible to remove profitably some very low grade ore.

*Future production.*—In 1911, for the State Tax Commission, Mr. J. R. Finlay estimated that Quincy mine would produce about 200,000,000 pounds more copper. The probable production of Franklin Junior and Hancock mines cannot be estimated yet. The area to be mined on these properties is large but the yield per ton at the Franklin has so far been low and the Hancock exploration is not yet far advanced.

*T. Macfarlane's description.*—Thomas Macfarlane of the Canadian Geological Survey, who examined the copper mines in 1865, thus described\* the Pewabic lode and its wall rocks:

"It has a thickness of about 12 feet, and in places resembles the rock which constitutes the foot wall of the mines, into which it seems to graduate. In its characteristic varieties it differs, however, completely from that rock. It is a reddish-brown or chocolate colored uncrystalline rock, with amygdaloidal structure, and uneven, almost earthy fracture. The matrix sometimes contains some small amygdules, which are not always completely filled, and thus render the rock porous. The matrix is fusible to a black slightly magnetic glass. It is in places impregnated with grains of metallic copper, from the minutest size to those having a diameter of a tenth of an inch. Those of a larger size generally project from the matrix into the amygdules or form rounded particles lying entirely within these cavities, and filling them. The copper is here accompanied by a mineral of a light green color, very soft, and separable from the rock as a green powder. It is probably a variety of green earth. Some of the amygdules are altogether filled

\*Report Geological Survey of Canada, 1866, pp. 152-154.

with it, in which case it frequently contains small isolated grains of metallic copper. Sometimes calcspar is found along with the green earth, the two minerals generally occupying separate parts of the cavity. Very frequently the green mineral merely lines the cavities and the rest is filled with calcspar.

"The foregoing description is of a specimen of the bed exceedingly rich in copper. At other places the matrix is more compact and darker colored, and the amygdules are exclusively filled with calcspar, without any enclosing film of green earth. Sometimes quartz, delessite, laumontite and prehnite occur, filling the cavities. In many parts of the bed large irregular patches and veins of calcspar are seen, through which, and through the adjoining rock, run large irregular masses of copper, frequently weighing several tons, with which small quantities of native silver are associated. Epidote is also often met with in the bed, generally unconnected with the amygdules and forming small irregular masses in the chocolate-colored rock."

"The rock which underlies the copper-bearing bed of the Quincy mine, is distinctly amygdaloidal [pseud-amygdaloidal?]. The matrix is fine-grained but it is crystalline, and is seen to consist of different constituents. Its color is dark reddish grey, and it is fusible to a black glass. The cavities, which seldom exceed the size of a pea, are filled with what appears to be the same chloritic mineral which occurs as a constituent in the rock above described. The specific gravity of the rock, including the amygdules, is 2.78."

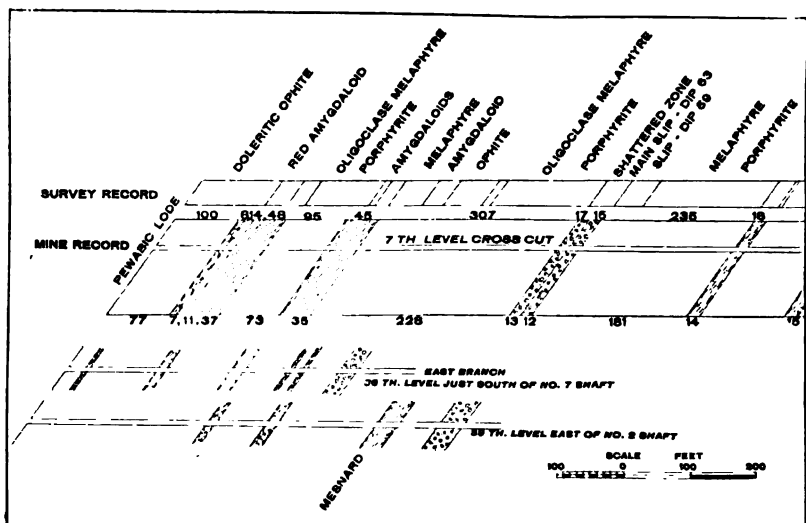


Figure 20. Sections at 7th, 36th and 59th levels of the Quincy mine (after Lane).

Mr. Macfarlane analyzed the rock and found it to consist essentially of labradorite and delessite (a variety of chlorite). He states of the hanging-wall rock that "It is a fine-grained mixture of reddish-gray feldspar, and dark green delessite, the former predominating. In this mixture larger crystals of feldspar, and larger rounded grains of the ferruginous chlorite are occasionally discernible. Its specific gravity is 2.83."

Mr. Macfarlane says\* further concerning the lode.

"The width of the bed is from 6 to 30 feet and the average thickness 10 feet. According to the general experience at the mine, the thicker the bed the richer is the rock in copper. About two-thirds of the area of the bed is removed as remunerative, the other third, although it may contain some copper, is left standing, as unworthy of excavation. The amount of ingot copper yielded by the ground actually removed in 1864 was 562 pounds per cubic fathom. Assuming the specific gravity of the rock of the lode to be 2.7, it thus yielded 1.4 per cent. Of course the copper was unequally distributed through the rock and the true percentage would be at many places above, and at others below that just mentioned."

*Mass copper.*—Mr. C. E. Wright says† of the occurrence of mass copper at the Quincy mine:

"The largest mass ever found in the mine is now being cut up in the 170-fathom level, about 50 feet north of No. 2 shaft, and will weigh about 20 tons. The masses usually found are not to exceed five tons in weight. The product is about 40 per cent mass and barrel work and 60 per cent stamp rock."

*C. E. Wright's description.*—Mr. Wright says‡ of this lode as it was known at the Quincy in 1881, where it had then been opened to a depth of 2,200 feet.

"The Pewabic lode, as developed in the Quincy, is a broad belt, 200 or more feet in width, through which runs a bunchy deposit or a series of connected deposits of amygdaloid; laterally, in the foot and hanging are also pockets of amygdaloid, which, when worked, are reached by cross-cuts from the main drifts. Altogether these make up the belt. The main lode is tolerably well defined and is followed, and the diamond drill, which for years has been employed in the mine, discovers the lateral pockets, many of which prove greatly productive in copper. They are sometimes in the foot, and as frequently in the hanging side. Nearly 300 borings have been made in the mine with the diamond drill, having an average length of 120 feet."

In another report Mr. Wright says:§

\*Report Geological Survey of Canada, 1866, p. 162.

†Report Com. Min. Stat. Michigan, 1880, p. 131.

‡Report Com. Min. Stat. Michigan, 1881, p. 110.

§Report Com. Min. Stat. Mich., 1882, p. 121.

"The Quincy mine is in the same lode with the Pewabic and the Franklin, but it differs materially from either of them in some important features that redound greatly to the advantage of the Quincy. The chief of these peculiarities are the so-called east and west branches which are found in the Quincy mine, and from which so great a portion of the product comes. They have been mainly found with the diamond drill and do not seem to occur in the mines west of the Quincy. The ground plan of the levels from the 80th down, show the main branch flanked by these laterals. Of these the east branch—the line of pockets found from the foot-wall—is by far the best. These lateral pockets, those which are the best, are from 60 to 100 feet from the main branch, and sometimes they prove very rich. The westerly pockets, or west branch, do not produce so well. The amygdaloid is harder, more "trappy," too much so to pay to work. Some of the pockets which make up the east branch are 200 to 300 feet in length, and all good stoping vein matter."

*Early workings at Franklin mine.*—At the old Franklin mine the testing for east and west lodes met for some time with little success, but a valuable deposit was opened up in 1888 at the 30th level. Supt. J. Vivian describes this lode in his report. He says:\*

"From time to time, for the last four or five years we have been exploring each side of the main lode with a diamond drill without the least success until July last, when we discovered, at the 30th level, 47 feet east of the main lode, an amygdaloid, 20 feet wide, bearing stamp and barrel copper in paying quantities. This lode has been opened at this level 288 feet, which has exposed some good stoping ground for at least 200 feet in length. The last eighty feet opened is not showing anything of value. In sinking a winze from the 30th to the 31st level some very rich stamp and barrel copper was met with. At the 31st level this lode has been cut into with a crosscut which has shown it to be copper-bearing for fifteen feet in width. Some good stamp rock and some barrel copper is being taken out at this point daily. At the 29th level this lode has been intersected with a crosscut, and opened on its line 128 feet. On the whole it is less productive than it is in the levels below, but some portions of it will afford some fair stamp rock, and will doubtless pay to stope. There is a large amount of ground ready for stoping on this lode that will yield in ingot copper above the average of the main lode."

*Variations in yield.*—The yield of refined copper per ton of ore mined at the Quincy in the years 1870-1881 is given in the following table from Chas. E. Wright's report for 1881.

\*Rept. 1888, p. 52.

	Tons mass copper produced.	Tons of ore stamped.	Tons concentrate produced.	Yield of refined copper per ton of ore stamped, per cent.
1870.....	86	55,027	1,437	2.61
1871.....	96	59,757	1,370	2.29
1872.....	100	60,828	1,302	2.17
1873.....	67.5	63,272	1,644.5	2.60
1874.....	58	67,112	1,752.7	2.61
1875.....	46	70,501	1,717.6	2.44
1876.....	65.75	74,717	1,765.5	2.38
1877.....	65.75	75,307	1,586.5	2.11
1878.....	70.25	92,800	1,634.25	1.76
1879.....	59.5	89,817	1,608	1.80
1880.....	83.5	84,426	2,355.75	2.50
1881.....	314.25	98,869	3,096.5	3.13

The figures for this period show that a fairly uniform grade of ore was being stamped. In the years 1861-1869, the average yield varied

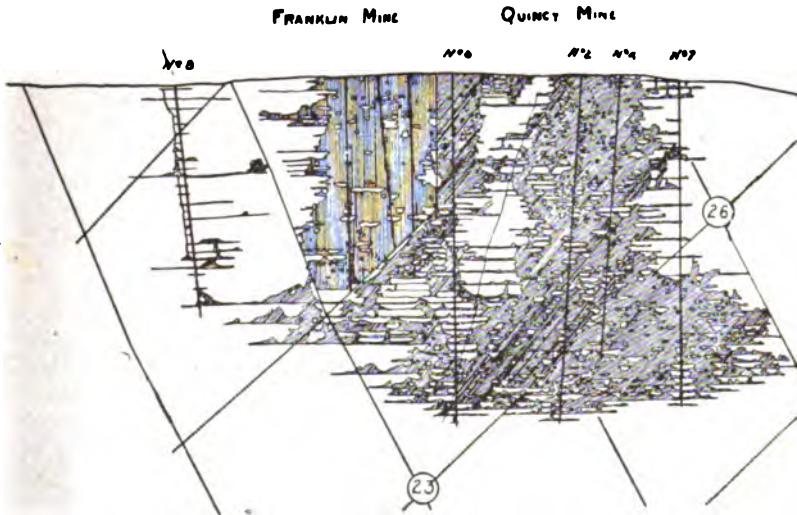


Figure 21. Stope map showing extent of workings at Quincy mine in 1893.

from 2.03 to 2.96 per cent, being lowest in 1862 and 1868. For the whole period of 21 years therefore, the yield was fairly uniform. In view of the richness of the ore mined in 1881 it is noteworthy that the mine was then 2,200 feet deep on the slope of the lode, and practically all of the ore was coming from below the 1,000 foot level.

For several years following the encountering of rich ore at depth the grade of ore mined continued high. As may be seen from the following table the period 1881-1891 was the best in the early history of the

mine. Later, the rich ore body having been worked out, the grade fell off again and for the past five years the yield has been only about 16 pounds copper per ton.

*Change in grade with depth.*—The change in character with depth is shown by the following table. In general the ore came from deeper levels each year, but there were other causes of variation in yield as will be noted in column headed remarks. The data are taken from the annual reports. The figures for succeeding years have not been made public.

YIELD OF QUINCY MINE ORE, 1864-1893.

	Average yield of copper per cubic fathom mined.	Remarks.
1864.....	562 pounds	
1865.....	501 pounds	
1866.....	451 pounds	
1867.....	526 pounds	
1868.....	427 pounds	The lode separated into two parts the larger and more productive dipping nearly vertically while openings had been made in the leaner branch.
1869.....	446 pounds	Increased yield resulted from opening main branch.
1870.....	528 pounds	Increased yield resulted from opening main branch.
1871.....	441 pounds	Decrease in richness of main lode.
1872.....	391 pounds	Falling off due to "pockety" character of the lode which was rich in places, with stretches of barren ground. At the 170 and 180 fathom levels, which were worked at this time, the lode was comparatively lean in copper.
1873.....	491 pounds	Increase due to opening up of rich lode to east of lode being worked. At No. 1 shaft a cross-cut at the 180 fathom level cut this lode at 60 feet east. This lode proved wide and rich. At No. 2 shaft also, the lode having become thin and poor, a cross-cut was run east at the 210 fathom level through 60 feet of hard compact trap and good ore was found.
1874.....	577 pounds	Increase largely to good ore from east lode but main lode also improved somewhat with depth.
1875.....	485 pounds	The lode at the points which had been relied on for the year's product proved much narrower than was expected and much more extensive openings were made to find new ore bodies. Drilling north at the 180 fathom level after passing through 80 feet of poor ground the lode became wide and rich.
1876.....	507 pounds	Ore largely from new ground opened north at No. 1 shaft and from the east branch at No. 2 shaft.
1877.....	467 pounds	No additional sinking was done in this year, the extension being by drifting to north and south.
1878.....	397 pounds	Ore chiefly from north and south extensions. The pockety character of the lode was unusually manifest, mass and barrel work being 48 per cent of the whole product. Many of the new openings were in unproductive ground.
1879.....	403 pounds	Openings were in poor ground and a large extent of hard narrow lode was encountered.
1880.....	563 pounds	Good ground was opened south of No. 4 shaft and also north of No. 2 shaft at the 24th level. Rich ore was also taken from south of No. 4 shaft at 14th level.
1881.....	767 pounds	Twenty-fifth and 28th levels were remarkably rich. All the levels below the 19th level and several above the 13th contributed to the product.
1882.....	800 pounds	The greatest yield per ton since opening of the mine. No. 2 shaft was 2,150 feet and No. 4, 2,090 feet deep. Several stopes were above average notably on 22d, 27th, 28th and 29th levels, though not so rich as 25th and 26th.
1883.....	850 pounds	Stopping of the past several years north of No. 2 shaft plainly indicates that the copper bodies have a decided pitch to the south. The best ore at No. 2 shaft at the 25th level was a considerable distance north, but at the 30th level it was close to the shaft.

YIELD OF QUINCY MINE ORE, 1864-1893.—*Concluded.*

	Average yield of copper per cubic fathom mined.	Remarks.
1884.....	722 pounds	The principal and most productive ground worked was at the 29th, 30th, 31st, and 32d levels at distance ranging from 300 feet south to 700 feet north at No. 2 shaft.
1885.....	710 pounds	The stoping done in the northern part of the mine was at various places between the 22d and 34th levels. The most productive ground worked was at the 32d, 33d and 34th levels. Most of the stoping done in the southern part of the mine was at the 31st, 32d, and 33d levels north and south of No. 4 shaft. The 32d, 33d and 34th levels were opened on the "East lode," about 50 feet east of the line of the old workings.
1886.....	638 pounds	Stoping chiefly in same parts of mine as in 1885.
1887.....	781 pounds	The principal stoping done at No. 2 shaft was at 30th, 31st, 32d, 34th and 35th levels north and in a rich block of ground at 33d level south; at No. 4 shaft principal stoping was between 31st and 35th levels north and south.
1889.....	690 pounds	Stoping at No. 2 shaft was at 37th and 38th levels north and south of shaft, at 36th, 35th, 34th and 33d levels north; at 32d, 31st, 30th and 20th north and south of shaft. Stoping done at No. 4 shaft was at 37th level south; at 36th, 35th and 34th north and south; at 33d, 32d and 31st south; at 27th north and south; at 25th south and 16th north and south.
1890.....	769 pounds	Principal stoping at No. 2 shaft was at 39th, 32d and 30th north; at 38th, 37th, 36th, 35th, 31st and 30th north and south at 33d, 26th and 25th levels south. Principal stoping at No. 4 shaft was at 40th and 29th north; at 39th, 38th, 37th, 36th, 34th, 27th and 16th north and south at 23d, 32d, 31st and 30th levels south.
1891.....	685 pounds	Stoping at No. 2 shaft was at 41st, 40th, 39th and 38th north and south; at 37th, 36th, 35th and 34th north; at 26th south and 24th north. Stoping at No. 4 shaft was at 16th north and south; 30th, 31st, 32d, 33d south; at 34th, 35th, 37th, 38th and 39th north and south; 40th south and 41st south.
1892.....	572 pounds	Stoping at No. 2 shaft at 41st, 40th, 39th, 38th, 37th, 36th, 35th, 34th, 33d, 32d, 31st north; 41st, 40th, 39th, 33d, 32d, south. Stoping at No. 4 shaft at 41st, 40th, 38th, 37th, 35th, 32d, 26th north; 41st, 40th, 39, 38th, 37th, 36th, 34th, 33d, 32d, 31st, 30th, 29th, 28th, 16th south. Some stoping was done at No. 6 shaft.
1893.....	574 pounds	Stoping at No. 2 shaft at 44th, 42d, 41st, 40th, 39th, 38th, 37th, 36th, 35th, 34th, 33d, 32d north; 44th, 43d, 42d, 41st, 37th, 36th, 34th and 26th south. Stoping at No. 4 shaft at 44th, 43d, 42d, 41st, 39th, 38th, 37th, 36th, 35th, 33d, 32d, 16th and 10th south; 43d, 42d, 41st, 40th, 38th, 37th, 34th, 33d north. Stoping at No. 6 shaft at 40th, 39th, 38th, 36th, 35th north and south.

In considering the above figures it should be borne in mind that the amount of rock discarded varied. In 1880 about 20 per cent of the rock broken was discarded. However, the figures show fairly well the variation with depth.

At greater depth the ore is leaner; but the writer has not figures to show how much leaner. It is doubtful whether there are any records to show the yield of copper from the section of the lode immediately under that which had been mined in 1893. In subsequent years the workings were extended far to the north and the lowering in grade that one might deduce from inspection of the annual statement is an exaggerated one. Poorer ore was, however, encountered at lower levels as well as north and south.



## PHOENIX MINE VEIN.

Chas. L. Lawton quotes the following figures showing yield of copper from the Phoenix mine vein for successive years:

Year.	Total ground broken fathoms.	Yield copper PER fathom broken. (Pounds.)	Per cent ingot in rock hoisted.
1872	965.81	363	.0086
1873	1,468.65	441	.0087
1874	1,835.62	749	.0145
1875	2,469.76	599	.0135
1876	2,865.46	413	.0110
1877	2,799.51	312	.0078
1878	1,802.46	246	.0073
1879	2,274.57	243	.0109
1880	1,543.59	289	.0077
1881	1,260.40	359	.0090
1882	1,489.63	346	.0085
1883	2,000.24	319	.0092
1884	1,388.93	409	.0133
1885	768.92	457	.0151

## SUPERIOR LODE.

The Superior mine lodes are comparatively rich and are being mined very profitably. The main lode is quite thick; but the ore bodies so far developed are not of great length. At present the mine is regarded as a one-shaft producer.

Much of the Superior lode is a dense reddish brown rock seamed with calcite. In the dark colored rock there are numerous light colored streaks and patches and in these much of the copper occurs. Thin sections of the brown rock are almost opaque, showing very numerous black grains and red dust, probably iron oxides, and large patches of nonmetallic semi-opaque light colored aggregates stained with red iron oxide. Between these patches are clear grains of quartz. In places the semi-opaque aggregates show a finely matted structure possibly due originally to feldspar laths now altered to calcite, etc. The aggregate when treated with HCl effervesces readily and is evidently largely made up of granular calcite.

The pale colored streaks and patches seem to have formed by alteration starting at joints or minor cracks in the rock. In several cases a string of copper runs down the middle of the aggregate in the position of the original joint. The microscope shows in very thin sections that calcite is the chief constituent. Thicker sections are semi-opaque and resemble sections of the red rock except for the absence of black and red iron oxides.

Other specimens of the lode show a rock with dense brown colored ground mass enclosing remarkably numerous amygdules that are mostly quartz and calcite. One section shows numerous calcite veinlets in one of which are several elongated grains of copper. On either side of the veinlet are several large copper grains in rock which has evidently been altered and is largely made up of very fine granules of quartz and feldspar. In the part containing most copper the well rounded amygdules are lacking, but the amygdules closest to these much altered portions contain some small copper grains. The copper bearing portion of the section is much lighter in color than is the main mass of the rock. One section shows numerous light colored bands in a part without amygdules and down the middle of the light bands is a rib of copper. Irregular light colored patches near these bands enclose occasional grains of copper. Many of the specimens are traversed by thin calcite veins. One section of the brown rock shows a remarkable rounded plagioclase crystal which has the appearance of being corroded. It has been broken and the fracture sealed with quartz.

One section shows a calcite veinlet traversing a distinctly amygdaloidal portion of the rock. The veinlet contains several elongated grains of copper. On either side of the veinlet the rock is much fissured and altered and contains grains of copper. Further away the rock is less altered and shows no copper.

Specimens of ore from the Houghton mine are remarkably similar to those from the Superior mine and it is probably the same lode. A dull brown or greenish rock containing much calcite and enclosing numerous or few amygdules of calcite and quartz is the common type. A section of the greenish ground mass seems to be largely chlorite and calcite with numerous opaque non-metallic particles. The amygdules of quartz and calcite enclose numerous very small grains of copper. One amygdule shows a border of clear quartz without copper enclosing a dull aggregate of calcite containing several grains of copper. Other amygdules show grains of copper in clear quartz.

Dr. Hubbard calls attention to the evidence of fracturing having preceded the deposition of copper. He states that at the Houghton mine another lode, east of the Superior lode, shows brecciation on a large scale with subsequent deposition of copper.

#### SUPERIOR WEST LODE.

This is partly brown and red, partly grey and green colored. Both types contain abundant calcite and quartz. The brown rock has very numerous areas, amygdules and irregular fillings, that are largely composed of brick-red feldspar. In many cases the filling is nearly

all feldspar; but more commonly the feldspar occurs as a red border enclosing coarsely crystalline quartz or calcite. Yellow-green epidote is the chief constituent of several amygdules. Scattered irregularly through the brown rock are patches of a dull dark green serpentinous or chloritic substance.

The grey ore shows a dense grey rock containing numerous amygdules which are chiefly calcite, and enclosing patches of a soft light green serpentine-like substance which is studded with native copper.

Thin sections of the brown ore show a dense ground mass with numerous grains and patches of red and black opaque minerals. The black occurs as metallic grains and is probably magnetite. The red is not in well defined grains and is probably secondary hematite. Feldspar occurs in lath-like shapes as in the diabases. There are grains of copper in this ground mass, some isolated and some in ill defined veinlets of quartz, chlorite, etc. The secondary red feldspar is much decomposed and is stained with red iron oxide. It appears to be orthoclase. One feldspar crystal encloses numerous microscopic grains of copper. With the quartz in amygdules and veinlets there are small green crystals which show the properties of delessite. The delessite in some cases occurs as nested aggregates enclosed in coarse quartz grains, in other cases the green crystals form the border and project from the brown ground mass out into the clear quartz. In each case the quartz is younger than the delessite. One amygdule shows a border of yellowish epidote enclosing quartz, delessite and calcite. Several amygdules are composed of a pale green chloritic aggregate. In a clear quartz veinlet copper occurs both as isolated grains and in string-like forms.

#### WINONA LODE.

The Winona lode is the productive amygdaloid of the Winona mine. According to Dr. Lane it is probably a continuation of the Isle Royale lode. It is low grade and has not yet been very successfully worked, but has been recently opened up for production on a larger scale and may soon prove profitable if good prices are obtained for the metal. Much of the copper is unusually fine and is not readily saved by the concentrating apparatus. For 1911 and 1912 the yield was about 13 pounds per ton. It is hoped that a better yield can be profitably obtained by finer grinding.

The ore contains a very high percentage of epidote and is almost all of green color. Copper occurs frequently in fine particles in quartz and calcite.

The lode averages about 24 feet in width, but in places is 30 feet wide. It is easily distinguished from the darker colored trap hanging,

but owing to the readiness with which the latter breaks a good deal of waste is mined with the ore. Above the lode and parallel to it there is a well defined fissure which has a soft clay filling and which is evidently a surface along which much movement has taken place. This slipping plane is in places just above the lode, but is sometimes 10 feet back in the hanging. That portion of the hanging trap under the slip is naturally heavy ground and falls easily after exposure to the air.

The lode is not a simple amygdaloid top, but, as stated by Dr. Hubbard, has many vein-like characters as though it had filled fissures

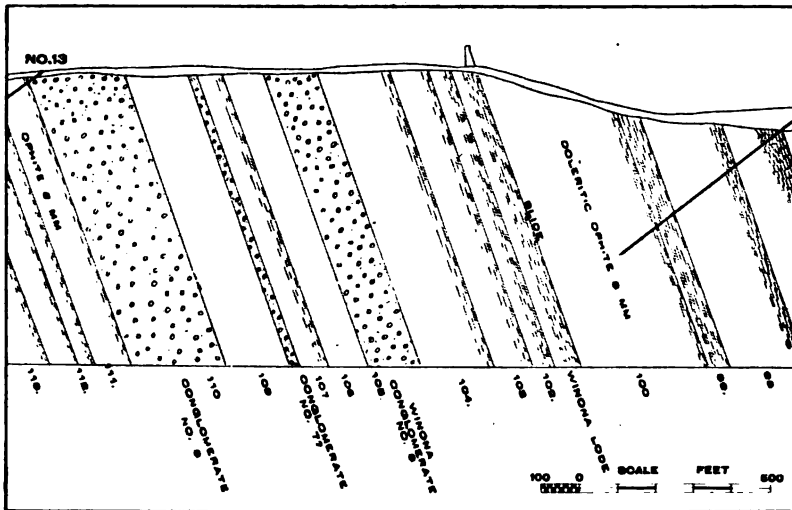


Figure 22. Section at Winona mine (after Lane).

more or less parallel to the bedding. The ore bodies do not continue very regularly and are separated by blocks of dense trap which generally contains very little or no copper, though in places it is fairly well mineralized. In mining the lode continuously therefore, much waste is broken and the practice is to sort out and discard about half the broken rock underground. In following the lode numerous slips are encountered and blocks of good ground are frequently found to be faulted into the footside of the main workings. Mr. Seeber says that many of these offset blocks of the lode are good ore, though some of them are lean. The main productive part of the lode shows a pitch to the southward.

The lode dips at somewhat less than 70°. The shafts are inclined at 70°, but extension of the workings has shown that the lode is not quite as steep as this. The strike is N. 58° E. and the dip S. W.

## PRODUCTION OF MICHIGAN COPPER DEPOSITS IN 1912.

(By lodes.)

	Tons of ore treated.	Pounds refined copper produced.	Yield in pounds per ton ore.
<i>Calumet conglomerate lode.</i>			
Calumet & Hecla Mine.....	1,746,960	51,935,245	29.3
Tamarack Mine (Including a small tonnage of Osceola amygdaloid ore).....	421,385	7,908,745	18.8
<i>Osceola amygdaloid lode.</i>			
Calumet & Hecla Mine.....	1,040,600	15,692,199	15.08
Tamarack Mine (A small tonnage included with conglomerate ore).....			
Osceola Mine.....	115,511	1,479,642	12.80
<i>Kearsarge amygdaloid lode.</i>			
Centennial Mine.....	106,517	1,742,338	16.36
Osceola (South Kearsarge) Mine.....	458,651	8,322,025	18.15
Wolverine Mine (1911-1912).....	401,308	9,408,960	23.45
Osceola (North Kearsarge) Mine.....	672,231	8,611,720	12.81
Allouez Mine.....	333,618	5,525,455	16.56
Ahmeek Mine.....	652,260	16,455,769	25.2
Mohawk Mine.....	787,941	11,995,598	15.22
Calumet & Hecla Mine.....	19,050	228,985	10.2
<i>Pewabic amygdaloid lodes.</i>			
Quincy Mine.....	1,309,253	20,634,800	15.8
Franklin Jr. Mine.....	176,462	1,710,651	9.8
<i>Isle Royale amygdaloid lode.</i>			
Isle Royale Mine.....	531,105	8,186,957	15.4
<i>Superior amygdaloid lodes.</i>			
Superior Mine.....	172,322	3,921,974	22.76
<i>Baltic amygdaloid lode.</i>			
Baltic Mine.....	652,433	13,373,961	20.50
Trimountain Mine.....	366,663	6,980,713	19.04
Champion Mine.....	765,306	17,225,508	22.51
<i>Winona amygdaloid lode.</i>			
Winona Mine.....	181,148	2,307,237	12.74
<i>Lake amygdaloid lode.</i>			
Lake Mine.....			
<i>Butler and Evergreen amygdaloid lodes.</i>			
Mass Mine.....	132,891	2,045,006	15.39
<i>Forest amygdaloid lode.</i>			
Victoria Mine.....	131,955	1,224,911	9.04



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## CHAPTER VI.

### ORIGIN OF THE DEPOSITS.

#### VIEWS OF GEOLOGISTS.

Many geologists have discussed the origin of the Michigan copper deposits. It is proposed here to summarize what has been written and then briefly to present the writers' views. The descriptions and deductions made by Dr. R. Pumpelly are especially worthy of study. Both are remarkable for clearness and accuracy.

*Dr. R. Pumpelly* from his studies drew among others the following conclusions:\* "1. The chlorite of the melaphyre, and consequently the distinctive character of that rock, is due to the alteration of hornblende or pyroxene. This seems to have been the first step toward the production of melaphyre proper. Laumontite, which we find alike in the beds containing the least and in those containing the most chlorite, and occurring both diffused and concentrated in seams, appears to have been formed either contemporaneously with the chlorite, or as the next step in the process.

"In the fissure-veins of Keweenaw County, laumontite is most abundant near and under the "Greenstone," as in the north end of the Central Mine. Here the great body of overlying rock is one in which the hornblende has undergone but little change.

"The next step appears to have been the individualization, in the amygdaloidal cavities, of non-alkaline silicates, viz.: Laumontite, prehnite, epidote respectively, according as the conditions favored the formation of one or the other of these.

"In the fissure-veins of Keweenaw County, prehnite is the most abundant silicate found in depth, i. e., below the 80 or 90 fathom level. The alkaline silicates are found chiefly in the upper levels.

"Following the non-alkaline silicates comes the individualization of quartz in these cavities.

"Perhaps we may be warranted in considering these minerals, together with the lime of the calcite that more rarely occurs in this portion of the series, as chiefly due to the decomposition of the pyroxenic ingredient of the rock.

\*Michigan Geological Survey, Vol. I, Part II, pp. 39-42.

“So far as we may infer from the tabulated results, the concentration of copper in the amygdaloidal cavities does not appear to have begun till after the formation of the quartz.

“In this part of the series falls also the formation of a chloritic or green-earth mineral, which in some manner has displaced prehnite, quartz, calcite, and with which copper, when present, appears to stand in intimate relation. Subsequently to this came the individualization of the alkaline silicates, viz., analcite, apophyllite, orthoclase. Here also seems to belong the formation of datolite.

“The alkaline silicates represent the period of decomposition of the labradorite ingredient of the original rock, and when they occur in the mass of the rock (as distinguished from veins), it is only where the alteration of the rock has proceeded so far that the amygdaloidal form has merged into the brecciated through the enlargement and union of the cavities.

“In the fissure veins of Keweenaw County, the alkaline silicates, as before stated, abound in the upper levels, and are rare in depth; in other words, they are abundant in that zone of the veins which lies between walls of those portions of the beds of melaphyr in which we should look for the most advanced stages of alteration in the components of the melaphyr, supposing such alteration to be due to the action of descending solutions.

“The fact that calcite occurs at almost every step in the paragenetic series, and forms one of the most common of the secondary minerals, is proof that carbonic acid was very generally present throughout the whole period of metamorphism; it was probably the chief mediating agent in the processes, without being sufficiently abundant to prevent the formation of silicates.

“II. The change of pyroxene to chlorite, as illustrated on an immense scale in the formation of the melaphyr, and the displacement of feldspar and quartz—quartz-porphyr—by chlorite, as exhibited in pebbles of the conglomerate, point to an extremely important line of investigation for the chemical geologist. The alteration of the pebbles appears to have followed two different directions according to the ruling conditions, viz., either toward chlorite or toward kaolinization; and as the result of the latter process is impregnated with calcite, while the result of the former is free from carbonates, it would seem that the direction was determined by the presence or relative freedom from free carbonic acid. The deposition of calcite, if formed from the acid carbonate, would set free sufficient carbonic acid to prevent the formation of silicates of iron and magnesia.

“III. Copper, wherever we can detect it with the eye, has already gone through a partial concentration. The presence of this metal in

minute quantity in the sandstones of Lake Superior, is made evident by the stains of carbonate which form on the cliffs of the 'Pictured Rocks.'

"It has also been found in the form of thin sheets of native copper occupying thin vertical fissures in the cliffs of Lower Silurian sandstone on the lake shore north of the Huron mountains. It is found here and there in the less amygdaloidal melaphyr in minute specks and impregnations, or even in a more concentrated form, as thin sheets occupying the joint-cracks.

"These occurrences increase in frequency in proportion as the rock is more amygdaloidal; in other words, the copper is more concentrated in those portions of the beds where the chemical change has been greatest. Where the rock has not passed beyond the strictly amygdaloidal stage, the copper occurs in the amygdules, traversing these in flakes, or coating them in a film of greater or less thickness, to such an extent as to form from one-fourth per cent to three per cent by weight, of the rock over considerable areas. Finally, in those beds where the metamorphism has proceeded to such an extent as to wholly replace large portions of the amygdaloid by secondary minerals, epidote, calcite, quartz, chlorite, laumontite, etc., there the copper occurs in masses of many pounds, and sometimes of several tons weight, and in forms equalled in their irregularity only by those of the masses of secondary minerals accompanying the metal.

"In each and all of these positions we find that the deposition of the copper took place subsequently to the decomposition and removal of a portion of the rocks, and subsequently to the deposition of laumontite, epidote, prehnite, and quartz, where these accompany it.

"In all this we have direct evidence of the movement of some salt of copper in wet solution, and the concentration of the metal by accumulating deposition in places where the precipitating agent existed.

"In the fissure-veins of Keweenaw County, the widening of the vein is frequently due to 'splicing,' i. e., a portion of the wall rock became detached and split by countless small cracks having a general parallelism to the main vein. Thus, instead of forming a solid 'horse of ground,' it consists of myriads of small and large lenses of often wholly decomposed rock, surrounded by films and seams of chlorite, laumontite, calcite and clay. These places are often the home of large 'masses' of copper, which then also have a spliced structure. Where the masses occur in a gangue of calcite, they are not spliced, but have a solid texture and the most irregular shapes. These facts point, perhaps, toward the formation of 'masses' by replacement.

"According to Mr. Pietrie, the superintendent of the Central mine (fissure-vein), where a 'horse' occurs in the vein, the regular vein

filling follows the foot-wall side of the 'horse,' and the younger fissure on the hanging-wall side is filled with calcspar and mass-copper. The foot-wall branch contains (like the regular filling elsewhere) prehnite, one of the earlier-formed minerals."

*Dr. R. Pumpelly* says further with reference to the origin of the copper deposits:\*

"The position of the metallic copper in the paragenetic series, shows it to have been deposited after the non-alkaline silicates and before the formation of the alkaline silicates, i. e., after those minerals which resulted from the decomposition of the pyroxenic constituents of the rock, and before those which were formed by the destruction of the feldspar. Now this is what we should expect if we suppose the pyroxenic rock to have been altered to its present condition under the cooperation of water carrying carbonic acid and some free oxygen, because the oxygen must have been employed in oxidizing the carbonate of iron resulting from the decomposition of the pyroxene;† the oxidation of the sulphuret of copper could not, therefore, take place until the pyroxene had so far disappeared as to leave a relative excess of oxygen as compared with the amount of ferrous salts exposed to a higher oxidation. Throughout its deposits the copper exhibits a decidedly intimate connection with delessite, epidote, and green-earth silicates, containing a considerable percentage of peroxide of iron as a more or less essential constituent; while among the other silicates, viz., analcite, laumontite, datolite, prehnite, only the last named, which alone seems subject to a considerable replacement of its alumina by ferric oxide, is especially favored by copper. This association is so invariable and so intimate that one is forced to the conclusion that there exists a close genetic relation between the metallic state of the copper and the ferric condition of the iron oxide in the associated silicates; that the higher oxidation of the iron was effected through the reduction of the oxide of copper and at the expense of the oxygen of the latter.

"As regards the green-earth and that variety of chlorite or delessite which is intimately associated with the copper, they either immediately follow the copper in point of age or are contemporaneous with it, and they may be looked upon as having been formed under the influence of this reduction. Where copper is associated with prehnite it is invariably younger than the latter, a fact which would seem at first glance to oppose the supposition that there is any relation between the peroxide of iron in the zeolite and the deposition of the copper. But we have seen that prehnite undergoes a change to delessite; we find these pseudomorphs in every state of the process from the first

\*Michigan Geological Survey, Vol. I, Part II, pp. 44-45.

†The result of this oxidation is seen in the brick-red color of the amygdaloids and in the brown color and spots of many of the melaphyr beds.

green discoloration on the cleavage planes to the amygdules of delessite, with prehnite structure. Now, may we not consider the presence of iron in prehnite generally to be due to a beginning change, and the deposition of native copper in the Lake Superior prehnites to be partially or wholly correlated with the higher oxidation of the iron?

"In at least very many instances, if not in all, the deposition of the copper has been a result of a process of displacement of pre-existing minerals. In some rare instances the metal retains the form of its more or less remote predecessor, as in the pseudomorphs after some mineral (clay?) after laumontite.

"Nowhere is this displacement more apparent than in the cupriferous conglomerates. In these, the cement is the home of the metal, and in some places, as in portions of the Hecla and Calumet mines, it is wholly replaced by it; copper forming 20 to 50 per cent., by weight, of the rock. In these instances, either chlorite or epidote is associated with the copper as minerals formed since the deposition of the conglomerate, while calcite very frequently replaces the cement in barren portions of the bed.

"The cement of the conglomerate is of the same materials as the pebbles in a more comminuted form. The displacement of the whole mass of quartz porphyry in large pebbles by chlorite and copper described above, is probably an illustration of the manner in which the cement was displaced on a more extended scale."

*R. D. Irving* in *Mono. X*, U. S. G. S. says: "The differences in origin of the several classes of copper deposits—conglomerate beds, cupriferous amygdaloids, epidote veins parallel to the bedding and 'fissure' veins transverse to it—which at first sight seem to be great, on closer inspection for the most part disappear. They are all the result of the percolation of carbonated waters, which, in the lines of fissure, the open textured amygdaloids, and the nearly equally open conglomerates, found the least resistance to their passage, and at the same time the greatest susceptibility to their altering power. This susceptibility depended partly upon the very openness of these different rocks, but also, in the case of the amygdaloids, in the presence of a large proportion of glass basis, the most readily alterable substance among rock constituents.

"The source and the cause of the arrest of the copper which was carried in with the altering waters are other and more difficult questions. Its home has commonly been regarded as being within the mass of the trappean flows themselves, with which it is supposed to have come to the surface. Another view is that it was originally deposited in a sulphuretted form along with the detrital members of the series, from which it was subsequently leached, partly in the shape of a sulphate,

but principally as a carbonate and silicate. The latter is the view which Pumpelly has elaborated;\* to whom also is due the credit of having advanced the only satisfactory view as to the cause of arrest of the copper in the places where it is now found. He has shown the existence of an intimate relation between the precipitation of the copper and the peroxidation of the ferrous oxide of the augitic constituent of the basic rocks; a relation so constant as to render irresistible the conclusion that in this ferrous oxide is to be found the precipitating agent of the copper. To this I would add that the ferrous oxide of the magnetite and of the unindividualized magma of the vesicular layers, has also been concerned in this reaction."

*M. E. Wadsworth* in a paper presented at the Lake Superior Meeting of the American Institute of Mining Engineers in 1897 considers the copper to have been derived from the volcanic rocks by percolating waters. He says:†

"From the fact that the copper is generally found most abundantly under the heavy lava flows, and associated with minerals evidently the product of the decomposed lavas, it appears probable that the copper was once finely disseminated through the lavas, and has since been concentrated by waters percolating through them. This view is advocated by Muller, Bauermann, Marvine and myself, while a similar view has been advanced by S. F. Emmons to account for the origin and concentration of the Leadville ore-deposits."

He says of the deposition of the metal:

"The means by which the copper was concentrated and deposited as native copper, instead of occurring in the form of the usual copper ores, is an interesting and unsolved problem that awaits the attention of the chemist who is willing to give his time and thought to the subject, although Pumpelly advocates the idea that the principal agent is the oxide of iron. In this he has much to sustain him, and his view is generally adopted."

*Dr. Wadsworth* considered that the evidence shows that deposition of metal took place after the Keweenaw Series was complete. He says:‡

"That the copper was deposited after the copper-bearing series was complete is shown by the fact that it is found in fissures extending across the beds that could only have been produced after the beds were in place; by the fact that the copper was deposited subsequently to the jointing of the lavas, owing to its now being found wrapped around the pieces formed by jointing; and by the extension of the copper from one flow down into another as a continuous mass."

\*Geology of Michigan, Vol. I, Part III, p. 43.

†Trans. A. I. M. E., Vol. XXVII, 1897, pp. 694-695.

‡Trans. A. I. M. E., Vol. XXVII, 1897, p. 695. Also stated in Dr. Wadsworth's report, M. G. S., 1891.

*C. R. Van Hise* in his paper on "Some Principles Controlling Deposition of Ores" discusses the Michigan deposits as an example of ore bodies which have remained practically unchanged since their first concentration. He says:\*

"We have now seen that the zone of fracture is searched by the percolating waters; that metalliferous materials taken into solution by the downward and lateral moving waters are carried to the trunk channels of underground circulation. that in these trunk channels the metalliferous materials are precipitated in various ways. Thus a first concentration, by ascending waters giving sulphurets and metals of some of the elements, is fully accounted for.

"In some cases the deposits thus produced are sufficiently rich, so that they are of economic importance. In these cases, which undoubtedly exist, but which perhaps are less numerous than one might at first think, a concentration by ascending waters has been sufficient.

"A conspicuous illustration of ore-deposits of this class which may be mentioned are the metallic copper deposits of the Lake Superior region. The copper was in all probability reduced and precipitated directly as metallic copper from upward moving cupriferous solutions. The reducing agents were the ferrous compounds in the solid form, in part as magnetite and as solutions derived from the iron-bearing silicates. When the copper was precipitated, the iron was changed into the ferric condition.† It is well known that metallic copper once formed is but slowly affected by the oxidizing action. Oxidation has in fact, occurred in the Lake Superior region, but from the facts now to be observed, not to an important extent. An oxidized belt may have formed in pre-glacial times, but if so, it was swept away by glacial erosion, and sufficient time has not since elapsed to form another. The ore-deposits now worked, have apparently remained practically unchanged since the time of their first concentration. In this fact we have the explanation of the great richness of these deposits to extraordinary depths."

*C. R. Van Hise* in his paper on "Some Principles Controlling Deposition of Ores" says‡ of the Michigan copper deposits:

"A still clearer case of precipitation resulting from the influence of the wall rock is the well known occurrence of metallic copper about grains of magnetite and in the openings of sandstones, conglomerates and amygdaloid of Keweenaw Point. Where the copper is about the magnetite, it seems perfectly clear that the protoxide of iron in the magnetite was the reducing agent which precipitated the metallic

\*Trans. A. I. M. E. Genesis of ore Deposits, p. 353.

†"Paragenesis and Derivation of copper and its associates on Lake Superior," by R. Pumpelly, Am. Jour. Sci., Third Series, Vol. II, 1871, p. 353.

‡Genesis of Ore Deposits, Trans. A. I. M. E., 1901, p. 344.



copper. The metallic copper between the particles was doubtless precipitated by ferrous solutions furnished by the wall-rocks, which in many cases are basic volcanics."

*Franz Posepny* in his well known treatise on "The Genesis of Ore Deposits" says\* of the origin of the Michigan Copper deposits:

"Some of the attempted explanations assume, in my opinion correctly, as the cause of the first ore-depositions, the action of hot springs—in which connection it is only to be emphasized that these thermal effects occurred long after the intrusion of the eruptive flows between the sedimentary strata, so that the ores were brought, not by or in the eruptives themselves, but by the later springs, from great depths and perhaps from considerable distances. This explanation, applicable to all the deposits, suits also the exceptional case cited by R. D. Irving, namely, the Nonesuch copper-bed in the sandstone of Porcupine Mountain, far from an eruptive outflow."

*Waldemar Lindgren* in a paper† entitled "Metasomatic Processes in Fissure Veins, says of the Michigan copper deposits which he discusses under the heading of Zeolitic Copper Veins.

"The copper-deposits of Michigan are in part fissure veins cutting across the beds of melaphyre and other basic igneous rocks as common in that district. It is true, however, that the ore bodies of the large mines are not to be considered as fissure-veins, but rather as beds or strata along which copper has been deposited by a process of replacement."

He summarizes the descriptions and theoretical deductions of Raphael Pumpelly and R. D. Irving and states in conclusion:

"Especially remarkable is the series of replacements which, as shown by Pumpelly, has taken place in these veins. Prehnite is pseudomorphic after plagioclase; and many amygdaloids are largely prehnitized. The prehnite is again replaced by orthoclase; and finally, the latter may change into epidote and quartz. Sericite is absent.

"These copper-bearing veins are clearly very different from the majority of fissure-veins, and have been formed under very different conditions—in fact, probably not by the thermal waters. Of other classes, the orthoclase-albite-zeolite veins of the Alps are most closely related; while a certain slight resemblance also exists to the propylitic veins, emphasized by the chloritic alteration and the presence of orthoclase."

*Dr. Lindgren* in his recently published book on Mineral Deposits discusses the origin of the native copper and of the zeolites which occur with the copper in basic lavas. He points out that of all the occurrences of zeolites the most abundant and conspicuous is that in

\*Trans. A. I. M. E., 1901, p. 145.

†Trans. A. I. M. E., Genesis of Ore Deposits, 1901, pp. 606-608.

the blowholes of volcanic flows, and states that in many occurrences it can be shown that the zeolites formed as the last phase of consolidation of a magma. He discredits the frequently made statement that zeolites are formed as the result of leaching by surface waters and says:

“Zeolites are manifestly unstable in the zone of weathering and must have been formed at some depth. Of late years the opinion has been gaining ground that zeolitization, in basic volcanic rocks is distinctly connected with the cooling processes and in fact should be regarded as an after effect of volcanism, their deposition taking place in the still hot rocks.”

He believes, with Knopf, that any theory accounting satisfactorily for the zeolites will also account for the copper. He believes that the copper was first present in the rocks as a silicate and says:

“Following Lane, I believe that waters of seas or lakes, mingling with the exhalations from the magma, decomposed the copper silicate contained in the pyroxenes, and that the resulting chlorides of iron and copper were decomposed by silicates or carbonates of calcium, with the formation of native copper, ferric oxide, and calcium chloride.”

*J. H. L. Vogt*—It is interesting to note that J. H. L. Vogt who argues in favor of the theory of magmatic origin of many ore deposits, considers the Michigan copper as a deposition from underground waters as described by Van Hise. He says in his paper\* on “Problems in the Geology of Ore Deposits:”

“That the ore-deposits first mentioned above, viz., the titanite iron-ores in gabbro, the chromite-occurrences in peridotites, the nickel-pyrrhotite deposits in gabbro, etc. were formed by magmatic extraction, I think I have scientifically proved beyond doubt; and I believe that the magmatic-extraction theory advanced for the cassiterite and apatite-veins is in its main proposition correct. For the ore-deposits subsequently considered—the contact-deposits, the pyritic deposits, the gold-veins, silver-lead veins, copper-ore veins, etc.—the views here offered become confessedly more and more hypothetical. But they have much in their favor; and even if, following in particular the French observers, I have ascribed to magmatic-extraction too great a significance, I believe, nevertheless, that the hypothesis is worthy of thorough scientific discussion.

“At the same time, I wish to add emphatically that, beyond doubt, numerous ore-deposits may have been formed by the action of underground waters, so comprehensively investigated and described by Van Hise; e. g., many deposits of iron and manganese-ores; the veins

\**Trans. A. I. M. E., Genesis of Ore Deposits, 1901, p. 658.*

of nickel silicate (garnierite); pretty certainly also the native copper of Lake Superior; and many other occurrences."

*H. L. Smyth*, in a paper presented at Harvard University in 1896, discussed the origin of the Keweenaw Point deposits and a summary of his paper has been published in *Science*, February, 1896, p. 251. He points out that from the consideration of the conditions of formation of the separate flows, with their subordinate intercalated conglomerates, it is probable that each flow after consolidation was immediately subjected to the action of meteoric waters. "Afterwards by slow subsidence, each bed would eventually sink beneath their reach. . . . Afterwards came the northerly and northwesterly tilting, and the formation and filling of the fissures, and the impregnation and partial replacement of the amygdaloids and conglomerates. The new minerals of this period are sharply separated from the alteration product of the first (which they often replace) by their richness in alkalis, and the presence of fluorine and boron. The two periods, therefore, are far separated in time as well as by the character of the chemical agents at work and do not, as Pumpelly supposed, represent a continuous march of alteration." Prof. Smyth concludes that neither Pumpelly's view, that the copper had been brought down from the sandstones of the upper division of the series, nor Wadsworth's, that it had come from the lava flows themselves, is probable. On the other hand, the mineral associates of the copper, the time of formation and, in the case of the veins, the evident arrest of the copper-bearing solutions below the relatively impervious greenstone, all point to a deep-seated source and to ascending solutions as the transporting agent. As to the precipitating agent, Smyth does not accept the view that it was electrolytic in its nature, because the deposition was manifestly accompanied in so many cases by the chemical destruction of the cathode. He concludes that in spite of lack of confirmation by laboratory experiment, no theory so well explains the invariable deposition of copper to great depths as Pumpelly's viz., that it was effected by the reduction of copper salts by the ferrous oxide in the universally present chlorite.

*J. F. Kemp* has summarized and commented on some of the published views on the origin of the deposits as follows:\*

"The original source of the copper was thought by the earlier investigators to be in the eruptive rocks themselves, and that with them it had come in some form to the surface, and had been subsequently concentrated in the cavities. Pumpelly has referred it to copper sulphides distributed through the sedimentary, as well as the massive rocks from which the circulating waters have leached it out as carbonate,

\*Ore Deposits of United States and Canada, pp. 209-211.

silicate and sulphate. Although the traps are said by Irving to be devoid of copper, except as a secondary introduction, it would be interesting to test their basic minerals for the metal in a large way, as has been so successfully done by Sandberger on other rocks. It is probable that these may be its source.

"Irving states that the coarse basic gabbros of the system contain chalcopyrite, but they do not occur near the productive mines. The electro-chemical hypothesis of deposition was earliest advocated (Foster and Whitney), and on account of the electrolytic properties of the two metals copper and silver, at first thought, it seems to be a reasonable explanation. Still, the unsatisfactory character of all experiments made in other regions to detect such action militates against it. Pumpelly, however, has worked out an explanation much more likely to be the true one. He found, on studying the mineralogical changes which have taken place in the rocks, that the alteration had been very thorough, and that it had involved a most interesting series of minerals, which are now chiefly manifested in the cavity fillings. It is to be appreciated, as has been especially well shown by the recent detailed geological sections of L. L. Hubbard,\* that in the productive region, the Keweenawan rocks consist of a vast series of basic lava flows, with a few of more acidic types, and with occasional intercalated conglomerates. H. L. Smyth† has also emphasized the fact that these successive lava sheets must have remained for protracted periods after their outpourings, exposed to the atmospheric agents, and to weathering, before they sank beneath the sea, and were buried under the conglomerates. As a matter of observation, the upper portions of the sheets are notably more cellular and decomposed than are the lower. Two kinds of amygdaloids were indeed recognized by Pumpelly,‡ brown ones, or true amygdaloids, in which the alteration was excessive, and which were probably derived from cellular lava sheets; and green ones, or pseudo-amygdaloids, which are hard and dense, and probably owe their apparent amygdules to the decomposition of pyroxene, olivine or feldspar crystals. Pumpelly traces out the following series of minerals. The first to develop was chlorite. Either contemporaneously with the chlorite or next after it, laumontite, a hydrated basic silicate of calcium and aluminum resulted. Laumontite, prehnite and epidote, all non-alkaline silicates, next segregated in the cavities, and were followed by quartz. They are thought to correspond to the decay of the pyroxenic minerals in the lavas. The copper manifestly came in after this, and its deposition seems to have proceeded along with the formation of a green chloritic mineral, or green-

\*Geological Survey of Michigan, V., opp. p. 166.

†Science, February 14, 1896, p. 251.

‡Geological Survey of Michigan, I, Part II, 14 Amer. Jour. Sci., September, 1871. Proc. Amer. Acad. Arts and Sciences, XIII, p. 268, 1878. Geol. Wisconsin, III, 31.

earth, which has displaced the prehnite, quartz and calcite of the earlier stages. Calcite, it should be added, marks almost every stage of the paragenesis. Presumably the reducing action produced by the oxidation of  $\text{FeO}$  to  $\text{Fe}_2\text{O}_3$  in the production of the chloritic 'green-earth,' caused the reduction and precipitation of the copper from some aqueous solution of sulphate, carbonate or silicate. After all this had occurred a quite different series of minerals (except that calcite continued to form) was introduced, which are characteristically alkaline silicates. Analcite, apophyllite, datolite, and last, of all orthoclase, are the chief members. Pumpelly regards them as produced by the alteration of the feldspars of the basalts, and in a continuous succession of changes following those just cited, but H. L. Smyth advances the view that they and the copper came in after the tilting and faulting of the strata, and probably in uprising solutions along the fissures, which are illustrated in the vein mines. He remarks that apophyllite contains fluorine, and datolite boron, and that the mineralization of the fissure veins is often extended in lateral enrichments, where the fissures cut porous beds. Pumpelly specially favored the overlying sandstones and descending solutions as sources of the copper. Wadsworth gives a resume of all the views advanced up to 1880\* and himself favors a derivation by leaching of the neighboring and overlying trap.

"As stated in mentioning the great ore-shoots above, the circulations must have followed the general lines indicated by them, so that it is evident that the rich currents were of limited extent. The anomalous condition presents itself of native copper, a mineral that is usually characteristic of the oxidized zone of deposits of sulphides, extending to great depths below the ground-water level.

"It is natural to raise the query as to the possible passage of the native copper into sulphides in depth, but there is as yet no evidence of this change. Any minerals in the nature of sulphides are extraordinarily rare. A little whitneyite and domeykite (copper arsenides) and chalcocite occur in the amygdaloid, formerly worked at the Huron mine; chalcocite has been found in the Bohemian Mountains and in the Copper Falls mine. Native copper changes to chalcocite 90 feet down in the Mamaisne mine, near the Sault (L. L. Hubbard). A pocket of melaconite, the black oxide, was opened in the early days at Copper Harbor.

*Van Hise, Leith and Steidtmann.*—A brief statement of the views of several geologists who have discussed the origin of the ores is given by

\*M. E. Wadsworth, "Notes on the Geology of the Iron and Copper Districts," *Bull. Mus. of Comp. Zool.*, VII, 76, 123. Report of the State Geologist of Michigan, 1892, 167-170, and especially 169. Rec. also in a pamphlet of the Duluth, South Shore & Atlantic R. R., 1890. "Origin and Mode of Occurrence of the Lake Superior Copper Deposits." *Trans. Amer. Inst. Min. Eng.*, XXVII, 669.

Van Hise, Leith and Steidtmann in Monograph No. 52, pp. 580-581. They say:

"Irving,<sup>1</sup> Wadsworth,<sup>2</sup> and nearly all other geologists who have studied the copper-bearing rocks believe that the source of the copper was in the basic igneous rocks, and that so far as it was derived from the sediments, its ultimate source was still the basic igneous rocks, because the sediments came from those rocks. This belief is founded principally on the uniform and close association of copper with the basic igneous rocks and the known existence of copper sulphides minutely disseminated through some of the coarser igneous rocks. The source, of the copper was believed by Pumpelly<sup>3</sup> to be the overlying sediments.

"Smyth<sup>4</sup> believed that the ores did not come from the adjacent wall rocks but from a deep-seated source, the nature of which does not appear from this report.

"The conditions and agents under which the copper has been taken from the adjacent rocks and concentrated have been variously interpreted. Irving<sup>5</sup>, Pumpelly<sup>6</sup>, Wadsworth,<sup>7</sup> Lane<sup>8</sup>, and others have been inclined more or less strongly to the theory of concentration under the direct downward movement of meteoric waters. Pumpelly has also implied that concentration may have occurred when sediments were still below sea level. Lane<sup>9</sup> has suggested that the waters were sale waters of the type now found in the deep copper mines and that they represent fossil sea waters or fossil desert waters, which in the tilting of the series have migrated downward. Van Hise<sup>10</sup> has argued that while meteoric waters have done the work, it has been during their upward escape after a long underground course. Smyth assigned the first concentration of the ores to ascending solutions from a deep-seated source not specified."

*Messrs. Van Hise, Leith and Steidtmann* outline their own hypothesis of origin as follows:

"The copper ores are characteristically associated with basic igneous rocks. The source of the copper-bearing solutions lies in these igneous rocks. The original copper-bearing solutions were not. These solutions

<sup>1</sup>Idem. pp. 425-426.

<sup>2</sup>Wadsworth, M. E. The origin and mode of occurrence of the Lake Superior copper deposits; Trans. Am. Inst. Min. Eng., Vol. 27, 1898, pp. 694-696. See also Muller, Albert Verhandl. Naturf. Gesell. Basel, 1857, pp. 411-438; Bauermann, Hilary, Quart. Jour. Geol. Soc., Vol. 22, 1866, pp. 448-463; Wadsworth, M. E., notes on the iron and copper districts of Lake Superior; Bull. Mus. Comp. Zool. Harvard Coll., Geol. Ser., Vol. 1, 1880, p. 126.

<sup>3</sup>Pumpelly, Raphael, The paragenesis and derivation of copper and its associates on Lake Superior; Am. Jour. Sci. 3d ser., Vol. 2, 1871, pp. 188-198; 243-258; 347-355.

<sup>4</sup>Smyth, H. L., Theory of origin of the copper ores of the Lake Superior district; Science, new ser., Vol. 3, 1896, p. 251.

<sup>5</sup>Irving, R. D., op. cit., pp. 419-426.

<sup>6</sup>Pumpelly, Raphael, op. cit., pp. 353-355.

<sup>7</sup>Wadsworth, M. E. The origin and mode of occurrence of the Lake Superior copper deposits; Trans. Am. Inst. Min. Eng., Vol. 27, 1898, p. 695.

<sup>8</sup>Lane, A. C. The theory of copper deposition; Am. Geologist, Vol. 34, 1904, pp. 297-309.

<sup>9</sup>Lane, A. C. The chemical evolution of the ocean; Jour. Geology, Vol. 14, 1906, pp. 221-225.

<sup>10</sup>Van Hise, C. R., A treatise on metamorphism; Mon. U. S. Geol. Survey, Vol. 47, 1904, p. 1136.

<sup>11</sup>Op. cit., p. 251.

may be partly direct contributions of juvenile water from the magma, partly the result of the action of meteoric waters on crystallized hot rocks."

Van Hise, Leith and Steidtmann believe\* that the original deposition of the copper was limited mainly to middle Keweenaw time, or, if not, at least to the cooling period of the igneous rocks of that time.

They consider some of the gangue minerals to be hot-water deposits and state that the wall rock alterations associated with the ores seem to be such as are characteristic of hot water rather than meteoric solutions. They believe that part of the copper was deposited soon after the extrusion of the associated igneous rocks, but that much of the deposition of the copper followed the folding and deformation of the Keweenaw rocks, which accompanied and immediately followed the deposition of the Keweenaw series. They discuss the source of the thermal solutions, pointing out that the localization of the deposits in time and place seems to be something more characteristic of highly concentrated magmatic solutions than of a universally acting agent like meteoric waters working down from the surface, but that the juvenile waters were naturally more or less mixed with meteoric waters.

They say† in conclusion on this point :

"On the whole the evidence is taken to point to a probable original concentration of copper by hot solutions largely of juvenile contribution, but more or less mixed, necessarily, with meteoric waters and a later working over of the deposits by water dominantly of meteoric source. In any case there is a high degree of probability that the associated basic igneous rocks are the source of the copper deposits. The doubt arises only as to the manner of their derivation from these wall rocks—whether they are due to the escape of solutions of a juvenile nature before or during the crystallization of the lavas, or whether on the breaking up of the crystallized rocks by katamorphic alterations the minute portions of copper they contained were concentrated in the deposits."

*In the same report* Van Hise, Leith and Steidtmann discuss the chemistry of deposition of the ore and advance‡ the following hypothesis:

"Hot solutions containing copper chlorides, boron, and fluorine compounds, CO<sub>2</sub>, and possibly other magmatic emanations entered the porous parts of the formations, where they began the work of deposition and the solution and replacement of the wall rock. Hot solutions, in general, remove lime and soda with great rapidity. Pressure and CO<sub>2</sub> alone could cause the solution of alumina.§ In

\*Monograph No. 52, U. S. G. S., p. 582.

†Monograph No. 52, U. S. G. S., p. 587.

‡U. S. G. S. Mono. No. 52, p. 589-590.

§Gawalowski, A., Chem. Centralbl., pt. 1, 1906, p. 640.

general, there would be a tendency for the decomposition of all minerals in the wall rocks, and a consequent enrichment of the solutions in the constituents taken out of the wall rocks. However, as Lane\* suggests, the calcium silicate and sodium silicate in the solution would tend to keep magnesium out of solution. These processes would tend to develop chlorite by replacement and to keep magnesia permanently out of the solution. In general, chlorite is the most stable mineral from which magnesia assumes in the presence of hot solutions.† The first step in the cycle of deposition thus accounted for left the solution rich in lime, iron, and aluminum silicates. Changing conditions, perhaps, of concentration, heat, and pressure brought about the saturation of these constituents, and a generation of laumontite, prehnite, and epidote followed the development of chlorite. Silica became insoluble in this solution after the deposition of the lime-aluminum silicates, which resulted in the precipitation of quartz. The individualization of quartz was followed by the deposition of copper. It is suggested that the solutions were relatively rich in alkalies, probably the carbonates and chlorides both, when the period of copper deposition began, for the deposition of copper accompanied the solution of quartz and was followed by the deposition of alkaline silicates. Under these conditions copper-bearing solutions reacting with the ferrous silicates of the wall rock and perhaps with ferrous salts in solution in presence of alkaline carbonates caused the precipitation of copper. It is furthermore suggested that the deposition of calcite, coeval with the deposition of copper, was due to the interaction of alkaline carbonate and calcium chloride. As calcium chloride is a solvent of copper, its precipitation as a carbonate would give additional impetus to the precipitation of copper.”

*R. Beck and W. H. Weed* conclude‡ that:

“Genetically these deposits are best explicable by the assumption of a lateral secretion of the copper ores, which were originally finely distributed in the malaphyre. The only enigma is, why the resecretion and concentration took the form of native copper.”

*Frank F. Grout* in a paper§ on Keweenaw Copper Deposits of Minnesota shows that the copper occurs very commonly in the Keweenaw lavas. In the specimens examined he found that the more altered ores contained less copper than the fresh types, and he states that the copper occurs in the form of an insoluble silicate rather than as sulphide or native metal. Of the several types of lavas he considers the mottled melaphyres (ophites) to be specially favorable,

\*Lane, A. C., *Econ. Geology*, Vol. 4, 1909, p. 166.

†Steidtmann, Edward A., *Graphic comparison of the alterations of rocks by weathering with their alterations by hot solutions*; *Econ. Geology*, Vol. 3, 1908, p. 398.

‡*Nature of Ore Deposits*, p. 233.

§*Econ. Geol.*, Vol. V, 1910, pp. 471-476.



stating that they furnish not only a high per cent of the copper, but more ferrous iron for a reducing agent than the other types.

He gives the following analyses:

	Per cent copper.
1. Hackley diabase, Pine City, Minn., very fresh.....	0.029
2. Hackley diabase, Crooked Creek, Minn., average alteration..	0.020
3. Hackley diabase, McDermott Creek, Minn., extreme alteration.....	0.013
4. Mottled diabase, Taylors Falls, Minn.....	0.019
5. Hackley diabase, Crooked Creek, Minn.....	0.020
6. Conchoidal diabase, Crooked Creek, Minn.....	0.012

A. C. Lane has, in his monograph on the Keweenaw Series, summed up a number of facts bearing on the question of origin of the deposits. He calls attention\* to:

"1. The dissemination of copper in small quantities throughout the formation. The average from several thousand feet of drilling at the Clark-Montreal was 0.02 per cent. Hardly a single amygdaloid fails to carry less than .02 per cent copper, and when the copper content reaches .50 per cent it is nearly an ore.

2. The occurrence of native copper in similar formations of red rock associated with salt waters and lavas elsewhere—notably the New Jersey Triassic, in the Bolivian Puca sandstone, in Nova Scotia, around Oberstein in the Nahe melaphyre region, and in Alaska.

3. The general absence of native copper outside the Keweenaw, in the Lake Superior region but—

4. Native copper has been found in iron ores (generally thought to be formed by the action of downward working waters) in a few places.†

5. The water in the formation is of three kinds.

a. At and near the surface, soft and fresh with sodium in quantities more than sufficient to combine with the chlorine

b. At some distance (generally 500 to 2,000 feet, before it attracts attention, unless especially sought), the chlorine is higher and the water is charged with common salt. The line between the two classes of waters is often quite sharp.

c. At great depths a strong solution of calcium chloride containing some copper.

6. The middle water (b) often contains more salt than it could possibly have were it a mixture of a and c.

7. The lines between the different kinds of waters are not regular, yet the lowest water probably always comes within two or three thousand feet.

\*Publication 6. Michigan Geological and Biological Survey, 1912, pp. 41-43.

†Report for 1903, p. 247.

8. The amygdaloids seem, other things being equal, to contain rather stronger (more saline) water than the conglomerates.

9. An unequally heated solution corresponding in composition to mine water (c) will precipitate copper on the same minerals, prehnite, datolite, etc. on which it occurs in the mines, as Fernekes has shown.

10. The traps contain combustible gasses, as R. T. Chamberlain has shown.

11. Certain beds are abnormally high in copper for many miles.

12. Copper often replaces chlorite, and in the Calumet and Hecla pebbles chlorite replaces felsite, and the copper the chlorite.

13. Copper may even replace vein quartz.

14. Copper is formed generally after those minerals which are the products of alteration and contain lime, and before those secondary minerals which are the products of alteration and contain soda and potash.

15. Therefore, at the time the copper formed the mine water might have lost lime but could not have lost sodium. The rock might have lost both.

16. The Calumet and Hecla lode averages less rich (very rich in spots) near the surface, attains its greatest richness at a certain depth say about 2,000 feet, and then gradually decreases in richness.

17. The silver occurs more abundantly in the upper levels."

He then states: "The conclusion to which these facts have forced me is that the copper was in the Keweenaw formation as a whole, before being introduced into the particular places where we find it and that the deposits have gathered together by migration of the particles known as ions in the chloride solution, just as in the formation of electrolytic copper in an electrolytic bath the copper goes toward the electro negative pole and the more electro positive or alkaline parts of the solution, and as in Fernekes' experiments, toward the hotter parts of the solution."

*Dr. Lane* in concluding his remarks on the formation of the copper says:\* "It will be seen that my studies have led to no radical change in the views as to the origin of copper expressed by me in annual report for 1903 and by Wadsworth in the Transactions of the American Institute of Mining Engineers (XXVII p. 669) and by Pumpelly earlier.

"Copper should then be looked for not merely along pervious lines but near pervious lines, with a strong tendency to appear in hanging and foot and the mineral crest or richest part of a lode will be in the salt water belt, adjacent, either to right, left or below where the downward absorption has gone deeply."

\*Keweenaw Series of Michigan. Mich. Geol., Survey, 1912, p. 873.

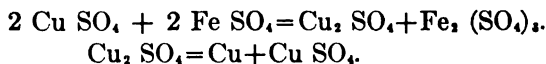
In summing up his studies on alteration of the minerals and composition of the mine waters, Dr. Lane states:\* "Pumpelly's theories seem to be altogether confirmed except that chlorine rather than sulphuric anhydride was the acid radical."

#### THE DEPOSITION OF COPPER BY SOLUTIONS OF FERROUS SALTS.

*H. C. Biddle* has discussed† the conditions under which copper may be deposited by solutions of ferrous salts. He cites several reactions by which copper has been deposited in the laboratory. He shows that in a solution containing few ferric ions and in which the reaction does not result in their appreciable increase a sufficient concentration of ferrous and copper ions will result in the deposition of metallic copper. He concludes from his results that the conditions under which the oxidation of ferrous salts may result in the deposition of copper are those which obtain, in underground waters and that the theory of Pumpelly and others based on paragenetic relations is thus fully sustained by chemical evidence.

*H. N. Stokes*.—Among the experimental investigations on solutions containing copper, those described in a paper‡ by Mr. H. N. Stokes are also of a nature to corroborate the views of Pumpelly. Stokes devised a simple apparatus to illustrate the behavior of hot ascending solutions. In the lower and warmer part the reaction between the mineral or metal and the solution was brought about, while in the upper cooler part the reaction was reversed, with deposition of the metal. The apparatus was filled with a solution of ferrous sulphate and cupric sulphate and the lower limb heated at 200° C. After an hour a crystalline deposit of copper was observed in the upper limb, and after 20 hours there was an abundant crystallization of copper. Hematite was deposited in the lower limb.

The reactions are represented by the equations.



The fact that a solution saturated with cuprous sulphate will deposit metallic copper on cooling, as represented in the second equation, had been previously shown by several investigators as stated by Mr. Stokes.

#### DEPOSITION OF COPPER FROM CHLORIDE SOLUTIONS.

*G. Fernekes*.—Having in view the fact that the copper mine waters are essentially chlorides with only traces of sulphates, Gustave Fernekes

\*Loc. cit., p. 868.

†*Jour. Geol.* Vol. IX, 1901, pp. 430-438.

‡*Economic Geology*, Vol. I, 1906, p. 644.

carried out experiments to determine whether copper would be deposited from chloride solutions in the same way as Dr. Stokes had found copper to be precipitated from copper sulphate solution by means of ferrous sulphate. In the preliminary experiments, carried out according to the method of Stokes, no copper was precipitated. This failure to precipitate copper from chloride solution Dr. Fernekes attributed to the fact that metallic copper is soluble in hot dilute hydrochloric acid whereas dilute sulphuric acid which was set free in Stokes' experiments has absolutely no effect upon the copper. The reactions which take place are—

1.  $2 \text{ FeSO}_4 + 2 \text{ Cu Cl}_2 = \text{Cu}_2 \text{ Cl}_2 + 2 \text{ Fe Cl}_2$ .
2.  $2 \text{ Fe Cl}_2 + 2 \text{ Cu Cl}_2 = 2 \text{ Cu} + 2 \text{ Fe Cl}_3$ .
3.  $\text{Fe Cl}_2 + 2 \text{ H}_2\text{O} = \text{Fe (OH)}_2 + 2 \text{ H Cl}$ .

Reaction three takes place at high temperatures and fairly dilute solutions.

Having determined that copper is deposited only when the acid liberated in this reaction is neutralized, Dr. Fernekes then added some of the minerals common in the ores and repeated the experiments. He found that in the presence of prehnite or datolite, copper is deposited. As these minerals are very common in the ores, the experiment has very important significance. Dr. Fernekes' description, as given in *Economic Geology* Vol. II, p. 581 is as follows:

"To make the precipitation of copper possible according to the above reactions, the hydrochloric acid must be constantly neutralized. This neutralization can be brought about by the carbonates or silicates of calcium and sodium. Calcium hydroxide was first tried, then calcium carbonate and finally calcium silicate in the form of the mineral wollastonite. The experiments were successful, the copper being deposited in from ten to fifteen minutes heating at 200° C.

"Complete precipitation required a somewhat longer time. It is evident that the more soluble the neutralizing mineral is in hydrochloric acid the more efficient it is for rapid neutralization and consequent precipitation of the copper. It also seems probable that we would be able to obtain crystalline copper more readily if a slower neutralization took place than in the above experiments where in fact the copper came down in a fluffy condition.

"At this point Dr. Lane suggested the following minerals, common in this region, which may have taken part in the neutralization of the free acid; labradorite, prehnite, laumontite, datolite, analcite and pectolite. Of these minerals the first three were present in the rocks before the copper deposits were formed and the last three are closely associated with the metal. The first four minerals were tried but

positive results were obtained only with prehnite and datolite. Since the conditions of the experiments, as finally carried out, were slightly different from those described by Stokes, it may be well to mention a few of the modifications introduced. Instead of employing a metal bath as did Stokes, an ordinary sand bath was used. The thermometer was placed alongside of the sealed tube containing the solutions. As explosions are not frequent this arrangement is perfectly satisfactory. The total length of the tubes employed was also greater, being about eighteen inches. The upper limb of the tube was surrounded by a water jacket. The temperature of the lower limb ranged from 200° C. to 280° C. The material was introduced into the tube in the following order; first about five grams of the neutralizing mineral, finely ground and freed from possible admixture of copper by treatment with nitric acid; then 0.2 grams of copper chloride; and finally a solution of ferrous chloride, containing an excess over that required to precipitate all of the copper. A few crystals of potassium bromide were also added. The solution which was always slightly acid, due to the ferrous chloride, was then almost neutralized by the action of sodium carbonate, filled to the top with water and sealed.

“In the case of prehnite, perfect circulation of the liquid about the mineral continued for about five hours when heated to 200° C. At the end of this time the basic iron salt formed in the reaction covered the small surface of the exposed prehnite to the height of two to three centimeters and consequently further action proceeded very slowly. Occasional cooling of the lower limb of the tube was therefore resorted to and by this means the solution was drawn back into the mineral, constantly exposing new surfaces. The tubes were heated intermittently for ten hours during the day. The heat was removed in the evening and again applied the next morning. After heating the solution and prehnite in this manner for five days an explosion took place at about 250° C. A portion of the side of the tube about five centimeters from the bottom was blown off, leaving a fairly hard cake underneath. On examining this cake of mineral with a small hand lens, it was found to be interspersed with shiny particles of crystalline copper. A few chemical tests were made. The particles were soluble in nitric acid with the evolution of brown fumes. They were insoluble in dilute hydrochloric acid, which fact distinguished them from cuprous oxide, and they precipitated metallic silver from neutral silver nitrate solution. The prehnite had become much darkened and the particles of the mineral were stained red in places with iron oxide.

“Datolite was acted upon in a similar manner for six days, at the end of which time minute crystals of copper could be detected throughout

the mass of the mineral. Experiments with laumontite and labradorite have up to the present time been unsuccessful."

AUTHOR'S CONCLUSIONS AS TO ORIGIN OF THE DEPOSITS.

*Some characteristics of the deposits to be considered in any hypothesis of origin may be here briefly restated.*

The copper occurs almost entirely as native metal. A little copper occurs as arsenides and sulphides in fissure veins.

The associated minerals are chiefly calcite, quartz, delessite, chlorite, epidote, prehnite and iron oxides.

The copper occurs in parts of the rock which show abundant evidence of decomposition.

Some copper occurs as a filling in fissures or porous beds.

Some copper occurs in fractures which extend along the beds, and also in minor fractures extending in all directions.

Most of the copper occurs as a replacement deposit.

In the amygdaloids some copper occurs in the amygdules; but most of it does not.

In the conglomerates most of the copper occurs in the matrix, but some in the pebbles.

The deposits are confined to the Keweenaw series and all but one of the important ones are in the lower part, which is very largely igneous.

Most of the workable deposits are amygdaloids, but the richest\* of all is the Calumet conglomerate which is interbedded with volcanic rocks.

Many of the deposits have thick and relatively impervious traps overlying them.

The amygdaloid lodes are parts of thick beds, mostly ophites. The lode rock seldom has a fresh crystalline appearance and is commonly a dull brownish or greenish mass of secondary minerals containing amygdules, seams and shapeless masses of calcite, quartz, epidote, delessite, and chlorite.

A consideration of these and other facts and a study of the literature leads the writer to the following conclusions:

The copper and the Keweenawan igneous rocks had a common origin. Two hypotheses present themselves: (1) the copper was deposited with the rock constituents, as silicate or other minerals, and subsequently dissolved and reprecipitated in the lodes as native copper, and (2) the copper was never so disseminated through the rocks and the native copper is essentially a primary deposit from solutions which accompanied and followed the extrusion of lava.

Abundance of chlorides in the mine waters indicates that the native

\*Exception must be made of the very rich but much smaller deposits in fissure veins.

copper was deposited from a chloride solution rather than from a sulphate solution. Sulphides are rare in the copper deposits and sulphates are only very occasionally found and it is therefore unlikely that sulphur was an abundant constituent of the solutions from which copper was deposited.

The copper is essentially a replacement deposit. Some has doubtless simply filled cavities in the porous rocks; but most of it has taken the place of other minerals which were decomposed and removed.

This replacement is not to be regarded as a secondary concentration long after the formation of the Keweenawan rocks, but rather as a result of reactions which took place while the rocks were still hot, though solid and fractured. The deposits are of Keweenawan age.

The occurrence of the same minerals with the native copper is remarkably characteristic of all the deposits and leads directly to the conclusion of a common origin for the copper of all the lodes, conglomerate beds, amygdaloid beds and fissure veins alike, as suggested by Pumpelly, Irving and Wadsworth.

Almost invariably there occur with copper the following minerals: Chlorite, epidote, calcite, quartz, prehnite and hematite. These, as Pumpelly has shown have, like the copper, replaced other minerals, and their formation was doubtless due in part at least to the copper-bearing solutions. Their constituents were for the most part present in the rocks in which they are now found and they are to be regarded as secondary minerals formed by the action not of ordinary meteoric solutions but by solutions partly of magmatic origin containing considerable copper and probably hot.

The deposition of the copper as native metal was probably due to reactions similar to those of Stoke's experiments with sulphate solutions; but from chloride solutions in presence of a neutralizing mineral as in Fernek's experiments. The abundance of ferrous iron in the minerals in the original rocks and of ferric iron in the altered rocks indicates clearly the presence of an efficient reducing agent as suggested by Pumpelly.

There is very little evidence in favor of the view that the deposits were formed by meteoric waters.

Because in many districts native copper occurs near the surface of sulphide deposits under such conditions that it is believed to have resulted from oxidation of sulphides, some geologists express the opinion that the native copper of the Michigan deposits has been formed as a secondary product by the oxidation of sulphides. In the opinion of the author there is no good reason to believe that the copper was first formed as a sulphide or that the copper was formed from any other mineral by meteoric waters near the surface.

Because numerous investigators have found that copper is a very common constituent of the Keweenawan rocks and occurs in small quantities in nearly all localities there is some reason to believe that there may be some copper present in the silicates, probably in the pyroxenes. Analyses of numerous specimens of so called "fresh" Keweenawan rocks have shown copper to be almost universally present. It does not follow that the copper is present in the silicates, however, as it is just as probably present as native copper. It is folly to assume that because native copper is not visible to the naked eye that it is not present.

The numerous Keweenawan rocks examined by the writer are all more or less altered. Some are called "fresh" because they appear comparatively little altered. It is merely a matter of degree.

The author is therefore of the opinion that while the copper may be present in the form of a silicate is just as probably present as microscopic particles of the native metal.

To state that the copper was first present as a silicate therefore only results in bringing into the question another unknown. There are unknowns enough already. The simpler hypothesis is by the author regarded as the better one. Of the two hypotheses (1) and (2) mentioned early in this discussion the author prefers (2) that the native copper is essentially a primary deposit from solutions which accompanied and followed the extrusion of the lava. The rocks were certainly fractured and possibly tilted before deposition of native copper ceased. It is possible that very little deposition took place before the rocks were extensively fractured.

It has been frequently stated that the ore bodies become gradually lower in grade with depth and that this points to formation of the deposits by descending waters. Before any useful deductions regarding the deposition of the copper can be made from the falling off in values with depth it is necessary to consider the facts more carefully. It is true that the ore now being mined at great depth is much leaner than that mined at some higher levels; but reference to descriptions of the various lodes will convince the reader of the inaccuracy of the general statements of gradual decrease with depth. The richer portions have terminated at some depth of course; but they terminate laterally in just the same way. There is no marked difference between the falling off in values with increase in depth and the falling off in values that is found in extending the openings laterally. Because some of the lodes are being mined for several miles it must not be imagined that the ore bodies are continuous. Rich and poor ground alternate. At and near the surface the lodes have been tested at intervals and the richer minable portions discovered. There is unfortunately no similar means of



locating any ore bodies which may lie at some distance below the present mine openings. The statement that the deep openings on the most productive lodes are in much leaner ore than was mined years ago is unfortunately only too true. It is not however a characteristic peculiar to depth alone. It is one that has taken longer to determine for depth than for length.

There is a remarkable similarity between the ore from near the surface and ore from depths of several thousand feet. Minor differences are noted, disintegration and some weathering has taken place near the surface. It is common experience that the lodes for the first few hundred feet are rather softer and more fractured than at greater depth. Yet the peculiar feature is that the ore is essentially the same; the same minerals occurring in the same way.

This uniformity in the character of the ore leads the writer to the conclusion that little change has taken place in the distribution of the copper since the deposits were first formed in Keweenawan time. The formation has been further tilted and faulted since deposition of copper ceased, and some secondary deposits have filled the later fractures formed; but the ore bodies themselves have been little changed. The lodes and enclosing rocks have been weathered and then glaciated. There is no reason to believe that the formation of the ore bodies has been in any way dependent on the present surface. The latter is the result of changes which took place long after the formation of the ore deposits.

#### *Summary of Author's Conclusion as to Origin of the Copper Deposits*

The native copper deposits were formed in Keweenawan time and have been but slightly altered since.

The native copper and the Keweenawan igneous rocks had a common origin.

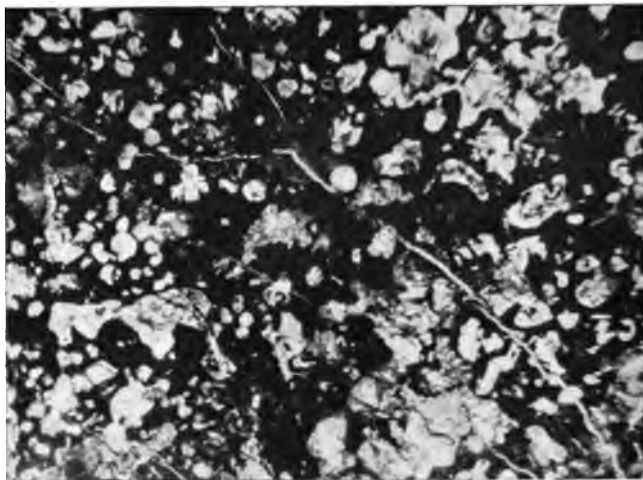
The native copper is essentially a primary deposit from solutions which accompanied and followed the extrusion of lava.

Deposition took place while the rocks were still hot; but after they were fractured.

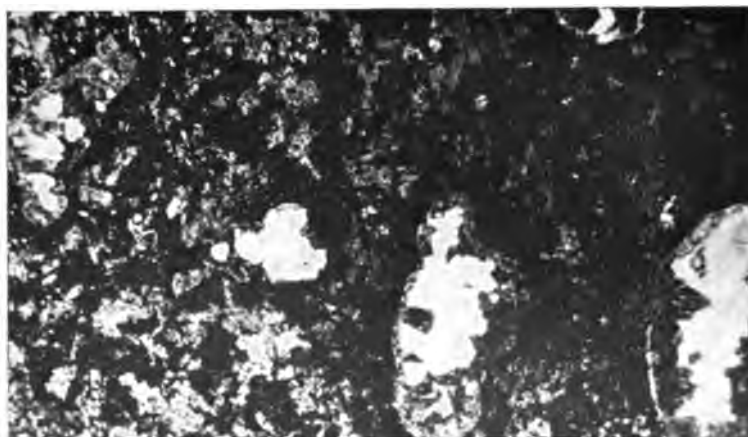
As pointed out by Dr. Hubbard, fracturing along or nearly along the bedding planes had occurred before deposition of copper ceased and possibly before any considerable deposition had taken place. The fracturing of the rocks was an important factor in determining the nature of the deposits, the fractures affording continuous channels for movement of solutions.

The deposits are replacement deposits.

The native copper was probably precipitated from a chloride solution.

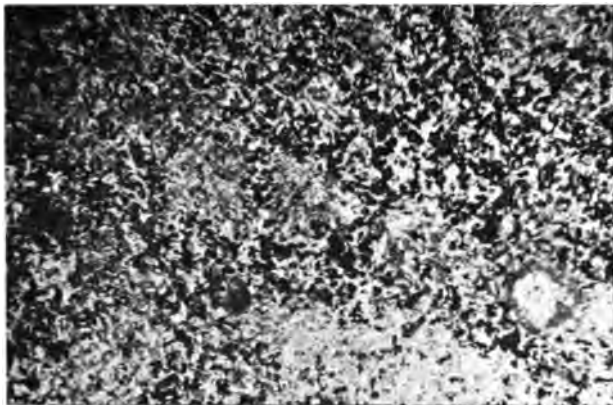


A. ALGOMAH LODGE, ALGOMAH MINE, ONTONAGON COUNTY. PHOTOMICROGRAPH X 10. THIS IS A VERY VESICULAR PORTION OF THE LODGE. SOME OF THE BLACK AREAS ARE MELACONITE, OTHERS THE DARK BROWN GROUND MASS OF THE ROCK. THE VEINLET AND SOME OF THE IRREGULAR AREAS ARE CHRYSOLITE.

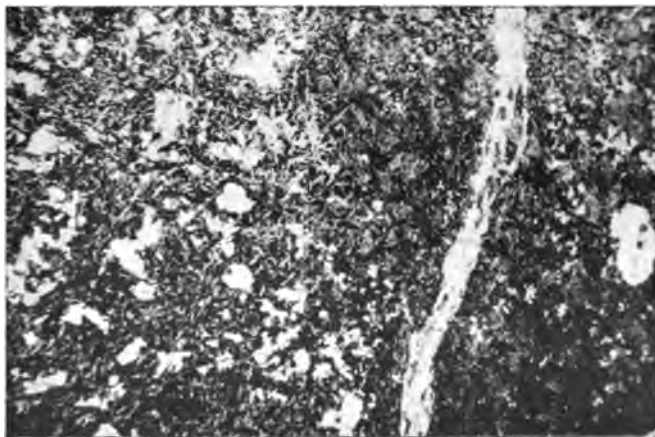


B. BUTLER LODGE, MASS MINE, ONTONAGON COUNTY. PHOTOMICROGRAPH X 10. THIS MICROSCOPIC SECTION SHOWS A FINE TEXTURED GROUND MASS AND AMYGDULES. THE LATTER ARE CHIEFLY COMPOSED OF RED FELDSPAR, QUARTZ AND CALCITE. THE DARK RED AND STAINED SEMIOPAQUE FELDSPAR FORMS THE OUTER PART OF THE AMYGDULE. THE CLEAR TRANSPARENT CALCITE AND QUARTZ WERE DEPOSITED AFTER THE FELDSPAR AND FILLED THE CENTRAL PART OF THE CAVITIES. THE COPPER IN THIS SECTION OCCURS IN FINE GRAINED GROUND MASS AND NOT IN THE AMYGDULES.





A. BALTIC LODE, BALTIC MINE. PHOTOMICROGRAPH X 10. THIS THIN SECTION SHOWS FINE GRAINED ROCK WITH VERY FEW CAVITIES. IT ILLUSTRATES THE TEXTURE OF A LARGE PORTION OF THE BALTIC LODE.

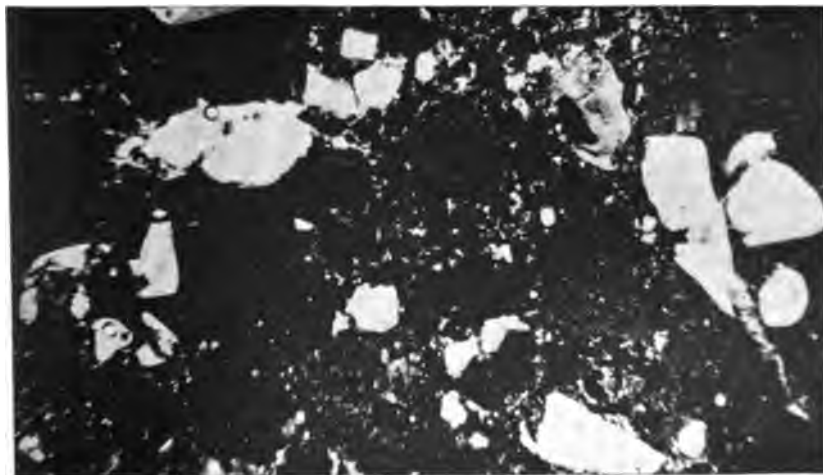


B. BALTIC LODE. PHOTOMICROGRAPH X 8. THIS SECTION SHOWS THE VESICULAR PORTION OF THE BALTIC LODE AND A VEINLET OF CALCITE. A CONSIDERABLE PORTION OF THE COPPER IS IN ROCK WHICH HAS BEEN FRACTURED AND LATER CEMENTED WITH CALCITE AND OTHER MINERALS. COPPER OCCURS IN FRACTURE FILLINGS BUT MORE LARGELY IN THE ALTERED ROCK NEAR THE FRACTURES.



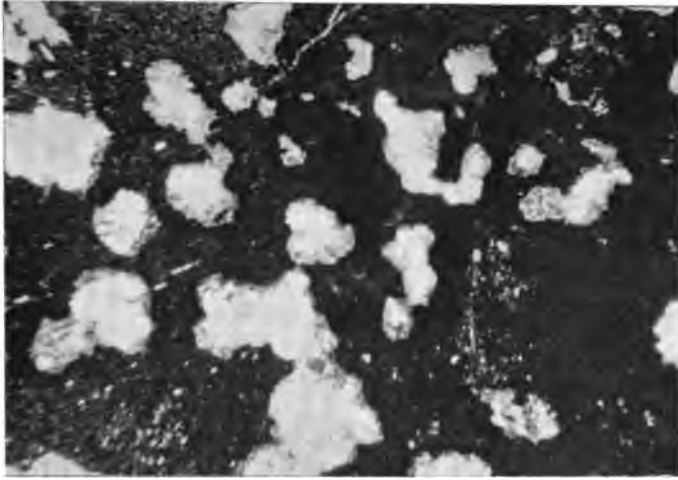


**A. CALUMET CONGLOMERATE, CALUMET AND HECLA MINE. PHOTOMICROGRAPH X 12. THIS IS A TYPICAL SECTION OF THE QUARTZ PORPHYRY OF THE CALUMET CONGLOMERATE SHOWING NUMEROUS CLEAR CRYSTALS OF QUARTZ IN A NEARLY OPAQUE FELSITE GROUND MASS. THE QUARTZ PORPHYRY PEBBLES CONTAIN SUCH NUMEROUS RED PARTICLES THAT THE GROUND MASS IS TRANSPARENT ONLY IN VERY THIN SECTIONS.**

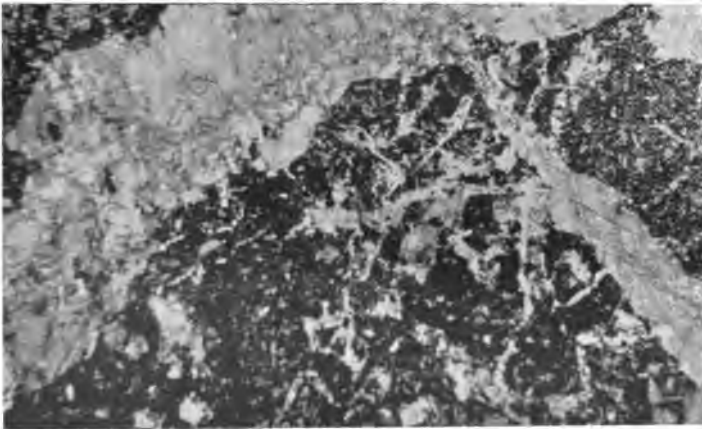


**B. CALUMET CONGLOMERATE. PHOTOMICROGRAPH X 8. THE CONGLOMERATE IS MADE UP LARGELY OF FRAGMENTS OF QUARTZ PORPHYRY BUT THE ROCK CONTAINS SO MANY MINUTE RED PARTICLES THAT IT IS NEARLY OPAQUE IN THIN SECTION. THE CLEAR TRANSPARENT AREAS ARE QUARTZ.**





A. HANCOCK NO. 3 LODGE, HANCOCK MINE. PHOTOMICROGRAPH X 10. THIS LODGE IS A TYPICAL AMYGDALOID. THE AMYGDULES IN THIS PARTICULAR SECTION ARE COMPOSED OF CHLORITE, QUARTZ AND CALCITE. MOST OF THE SEMI-OPAQUE CHLORITE HAS BEEN DEPOSITED EARLIER THAN THE CLEAR TRANSPARENT QUARTZ AND CALCITE.



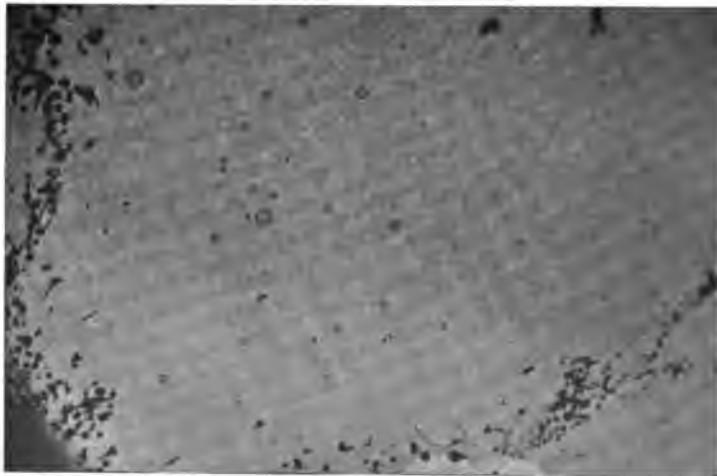
B. HANCOCK LODGE NO. 4, 34TH LEVEL. PHOTOMICROGRAPH X 8. THIS SECTION SHOWS VEINLETS OF CALCITE IN A NEARLY OPAQUE ROCK WHICH IS AN ALTERED PORPHYRITE.







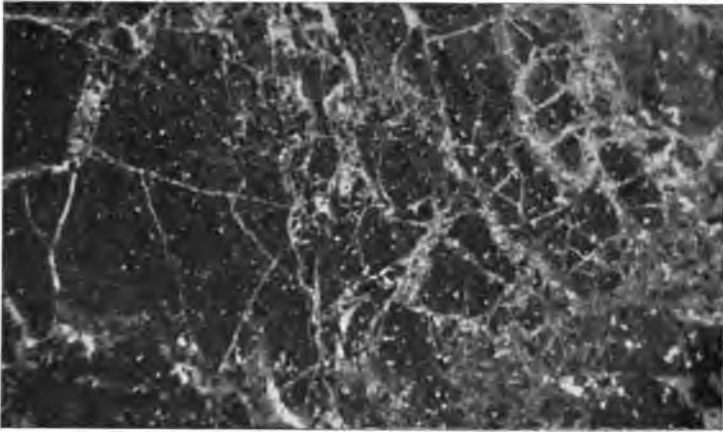
A. HANCOCK LODGE. PHOTOMICROGRAPH. THIS SECTION SHOWS NATIVE COPPER IN RATHER LARGE PARTICLES ALONG THE MIDDLE OF A VEIN OF PREHNITE. COPPER OCCURS ALSO IN SMALL PARTICLES IN THE ROCK ON EITHER SIDE OF THE VEIN.



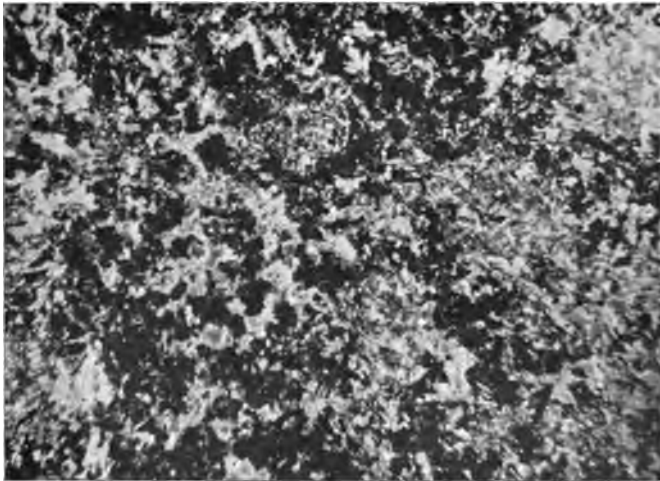
B. PHOTOMICROGRAPH X 9. THIS SECTION SHOWS MODE OF OCCURENCE OF NATIVE COPPER (BLACK) IN DATOLITE (WHITE). (RINGS ARE AIR BUBBLES IN THE BALSAM ON WHICH THE SECTION IS MOUNTED). FRANKLIN JUNIOR MINE.

THE DATOLITE OF THE FRANKLIN MINE IS A WHITE VARIETY. IT OCCURS FREQUENTLY AS ROUNDED MASSES SEVERAL INCHES IN DIAMETER. THE CENTRAL PART OF THESE MASSES IS OFTEN FREE FROM COPPER. NEAR THE OUTER EDGE, HOWEVER, NUMEROUS SMALL PARTICLES OF COPPER OF IRREGULAR SHAPE, AS SHOWN IN THIS HALFTONE, ARE GENERALLY FOUND.



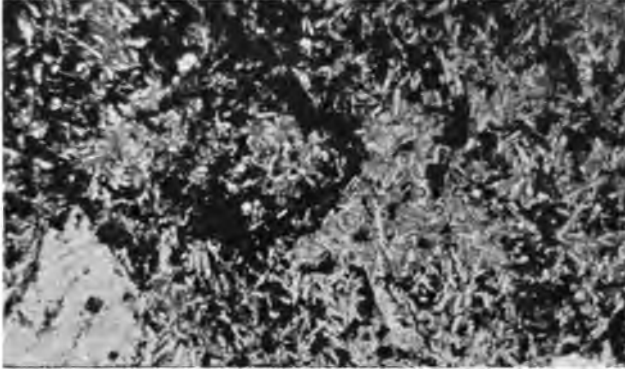


A. FELSITE, INDIANA MINE, ONTONAGON COUNTY. PHOTOMICROGRAPH X 10. THE FELSITE IS SEMI-OPAQUE OWING TO THE ABUNDANCE OF DARK RED COLORED PARTICLES. SEVERE FRACTURING IS INDICATED BY NUMEROUS VEINLETS OF COLORED MINERALS WHICH HAVE FILLED THE FRACTURES.

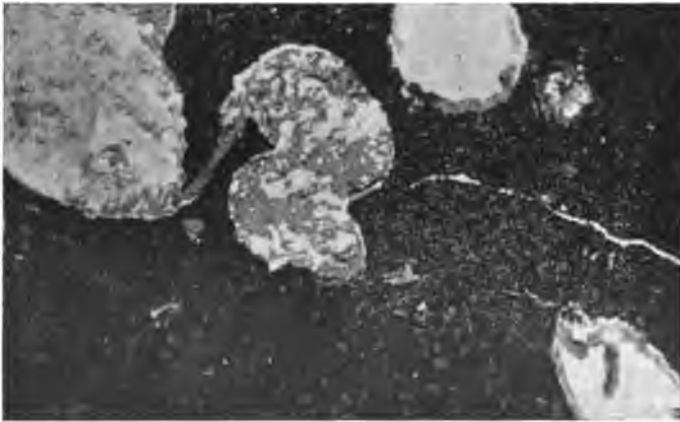


B. ISLE ROYALE LODE, ISLE ROYALE MINE. PHOTOMICROGRAPH X 8. THIS SECTION SHOWS A FINE TEXTURED ROCK WITH NO AMYGDULES. A CONSIDERABLE PORTION OF THE ORE HAS THIS TEXTURE. OTHER PARTS ARE QUITE VESICULAR.



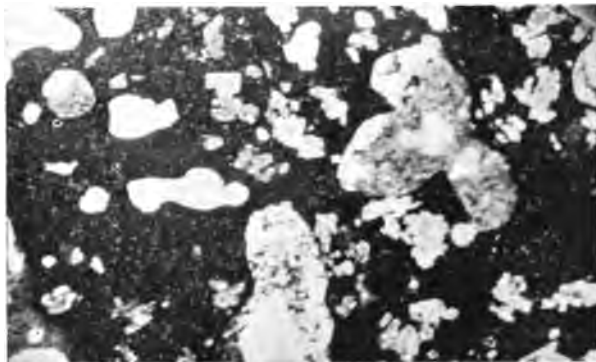


A. KEARSARGE LODE, MOHAWK MINE. PHOTOMICROGRAPH X 8. THIS SECTION SHOWS A RATHER DISTINCTLY CRYSTALLIZED PORPHYRITIC ROCK. THE SPECIMEN WAS TAKEN NEAR THE FOOT WALL OF THE LODE.

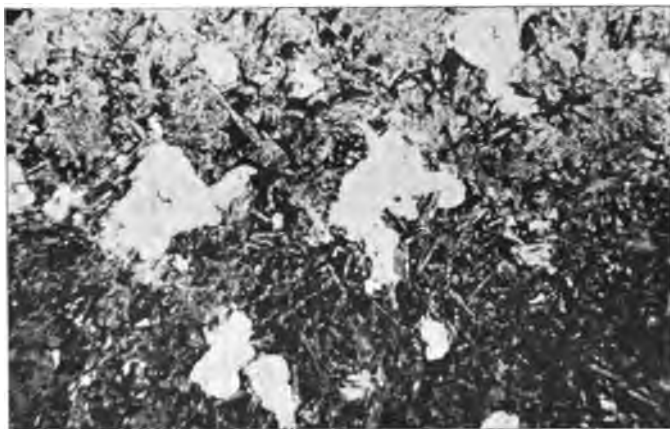


B. ISLE ROYALE LODE, ISLE ROYALE MINE. PHOTOMICROGRAPH X 10. THIS SECTION SHOWS LARGE AMYGDULES AND A VERY FINE GRAINED GROUND MASS. THE SEMI-OPAQUE MINERAL IN THE AMYGDULES IS EPIDOTE. THE CLEAR COLORLESS MINERAL IS QUARTZ. IN TWO CASES THE EPIDOTE FORMS THE MARGIN; IN THE OTHERS IT IS IRREGULARLY INTER-GROWN WITH QUARTZ.





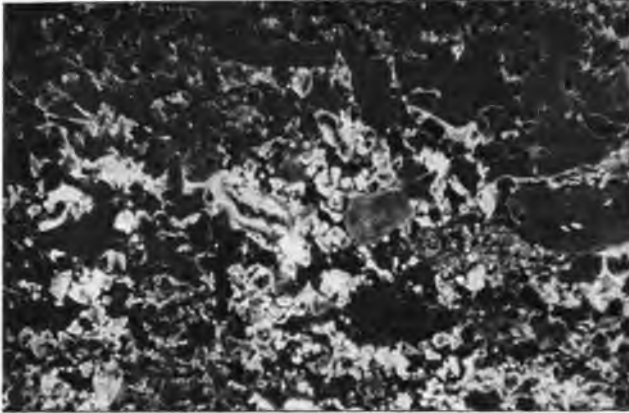
A. LAKE LODE, LAKE MINE. PHOTOMICROGRAPH X 12. THIS SECTION SHOWS BOTH AMYGDULES AND PORPHYRITIC FELDSPAR CRYSTALS IN AN OPAQUE GROUND MASS. THE AMYGDULES SHOW CLEAR TRANSPARENT QUARTZ AND CALCITE AND SEMI-TRANSPARENT CHLORITE.



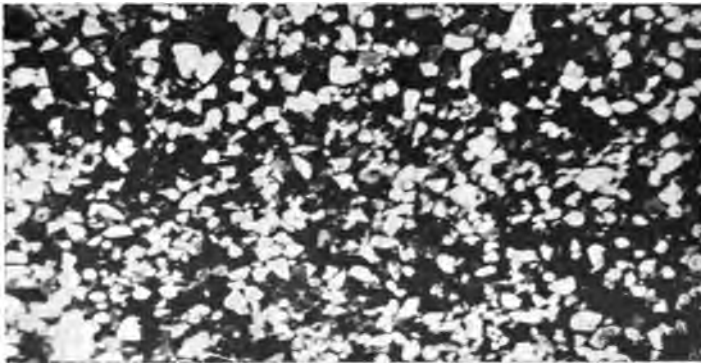
B. LAKE LODE. PHOTOMICROGRAPH X 10. THIS SECTION SHOWS A PSEUDOAMYGDALOIDAL PORTION OF THE LODE. THE CLEAR TRANSPARENT AREAS ARE CHIEFLY PALE GREEN CHLORITE. THE GROUND MASS IS DISTINCTLY CRYSTALLINE.





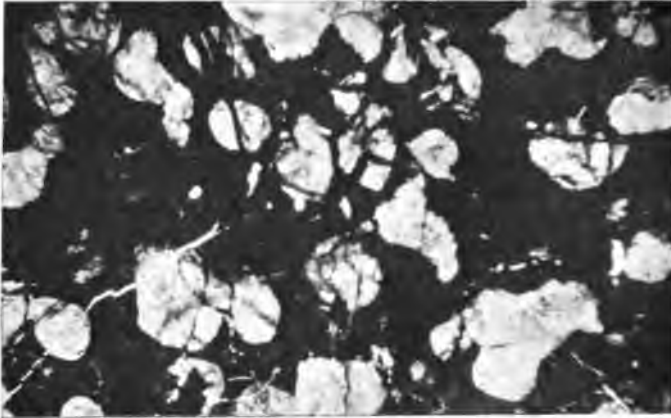


A. NONSUCH SANDSTONE, WHITE PINE MINE. PHOTOMICROGRAPH X 10. THIS SECTION SHOWS A FINE GRAINED CONGLOMERATIC ROCK. THE COLORLESS PEBBLES ARE QUARTZ. THE LARGE GRAINS ARE FELSITE AND MELAPHYRE. SOME OF THE SMALL OPAQUE PARTICLES ARE NATIVE COPPER.

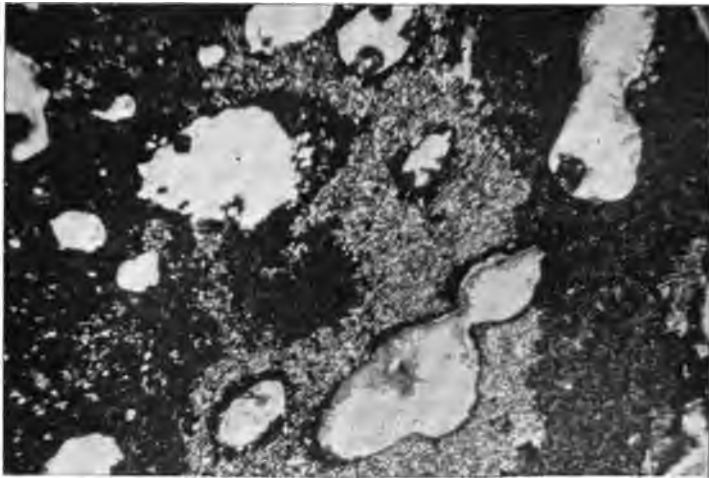


B. NONSUCH SANDSTONE, WHITE PINE MINE. THIS SECTION SHOWS A FINE GRAINED SEDIMENTARY ROCK COMPOSED CHIEFLY OF CLEAR COLORLESS GRAINS OF QUARTZ AND DARK COLORED ROCK PARTICLES. SOME OF THE OPAQUE PARTICLES ARE NATIVE COPPER AND SOME ARE MAGNETITE.





A. PEWABIC LODGE, QUINCY MINE. PHOTOMICROGRAPH X 8. PREHNITE IS VERY ABUNDANT IN THE ORE AT THE QUINCY MINE. THIS SECTION SHOWS NUMEROUS AMYGDULES OF PREHNITE IN THE OPAQUE GROUND MASS. SOME OF THE OPAQUE PARTICLES IN THE PREHNITE ARE NATIVE COPPER.

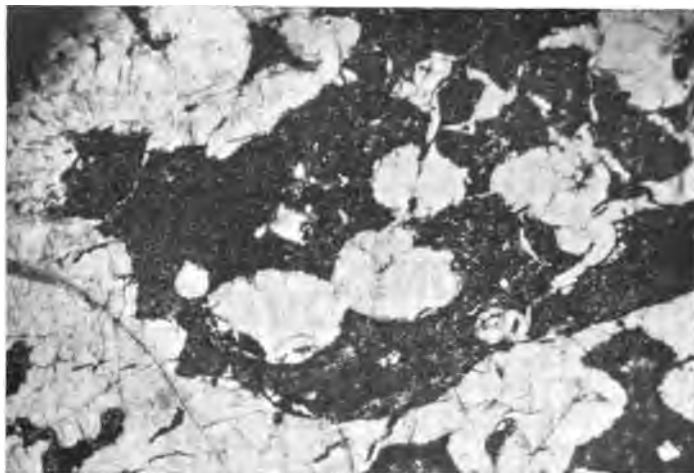


B. PEWABIC LODGE, FRANKLIN JUNIOR MINE. PHOTOMICROGRAPH X 10. THIS SECTION SHOWS A TRUE AMYGDALOIDAL PORTION OF THE LODGE. CRYSTALS OF DELESSITE (SEMI-OPAQUE) APPEAR AT THE BORDER OF CLEAR TRANSPARENT QUARTZ WHICH IS THE CHIEF CONSTITUENT OF THE AMYGDULES IN THIS SECTION.



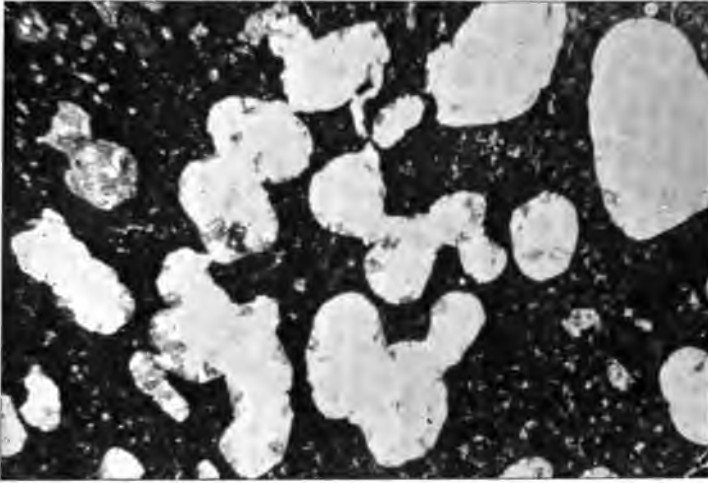


A. PEWABIC LODGE, QUINCY MINE. PHOTOMICROGRAPH X 10. THIS SECTION SHOWS A PSEUDO-AMYGDALOIDAL PORTION OF THE LODGE FROM NEAR THE FOOTWALL. THE LARGE TRANSPARENT PATCHES ARE SECONDARY CHLORITE. THEY HAVE NOT THE CHARACTER OF TRUE AMYGDULES.

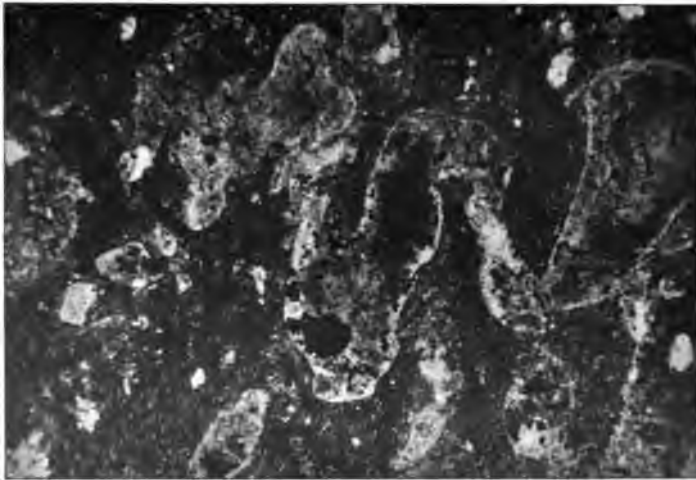


B. PEWABIC LODGE, QUINCY MINE. PHOTOMICROGRAPH X 8. NATIVE COPPER IN PREHNITE. THIS IS A PORTION OF THE LODGE WHICH HAS BEEN LARGELY REPLACED BY PREHNITE (WHITE IN PHOTOGRAPH). IN THE WHITE PREHNITE ARE SEVERAL IRREGULAR PARTICLES OF COPPER. THE MAIN DARK COLORED PART OF THE SECTION IS ALTERED ROCK CONTAINING PARTICLES OF NATIVE COPPER.





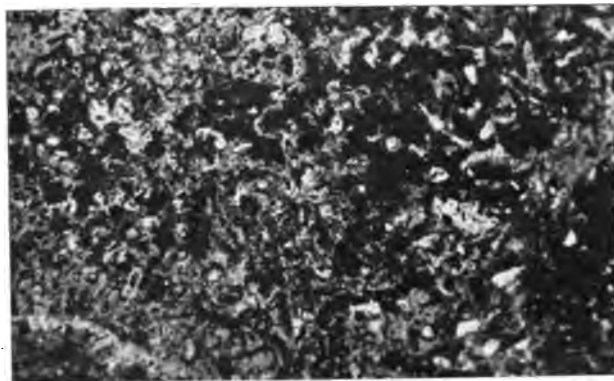
A. KEARSARGE LODGE, WOLVERINE MINE. PHOTOMICROGRAPH X 10. THIS SECTION SHOWS A TYPICAL AMYGDALOID WITH NUMEROUS LARGE AMYGDULES. THE CLEAR COLORLESS MINERAL IS QUARTZ. THE SEMI-OPAQUE CRYSTALS NEAR THE EDGE OF THE AMYGDULES ARE EPIDOTE.



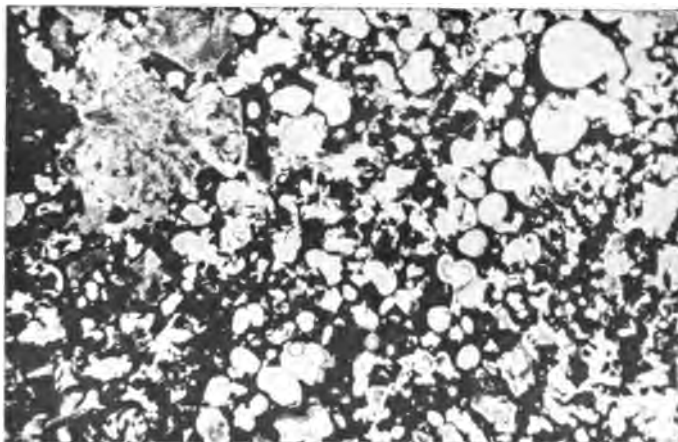
B. SUPERIOR LODGE, HOUGHTON MINE. PHOTOMICROGRAPH X 10. THIS SECTION SHOWS COARSE PARTICLES OF NATIVE COPPER IN LARGE AMYGDULES. IN THE DARK GROUND MASS THERE ARE NUMEROUS FINE PARTICLES OF METAL. THE LACK OF CRYSTALLINE STRUCTURE IN THE GROUND MASS IS NOTEWORTHY.



12. 12. 12.

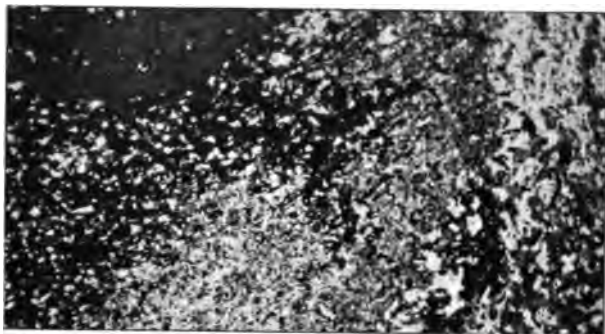


A. SUPERIOR LODE, SUPERIOR MINE. PHOTOMICROGRAPH X 12. THE COPPER IN THIS SECTION IS IN VERY SMALL PARTICLES SCATTERED THROUGH A FINE GRAINED ROCK.

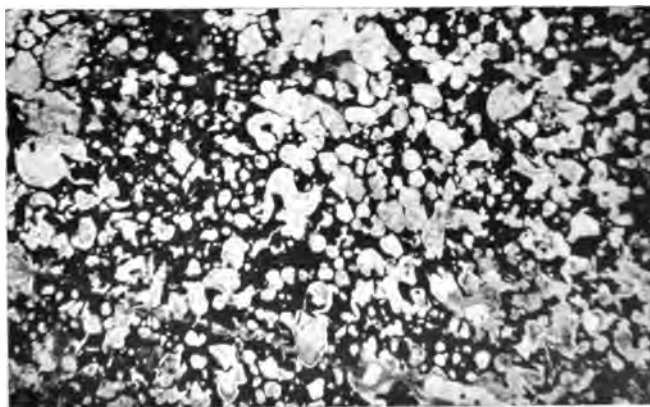


B. SUPERIOR LODE, SUPERIOR MINE. PHOTOMICROGRAPH X 10. THIS IS A REMARKABLY VESICULAR COPPER BEARING ROCK. THE AMYGDULES ARE CHIEFLY CALCITE. THE OPAQUE GROUND MASS IS MADE UP OF A CONFUSED AGGREGATE OF PARTICLES TOO SMALL FOR IDENTIFICATION.





A. SUPERIOR LODGE, SUPERIOR MINE. PHOTOMICROGRAPH X 10. THIS IS A DULL BROWN MASSIVE ROCK SHOWING NO COPPER TO THE NAKED EYE. NUMEROUS SMALL GRAINS OF COPPER ARE, HOWEVER, READILY OBSERVED UNDER THE MICROSCOPE. THE ORIGINAL TEXTURE OF THE ROCK HAS BEEN OBSCURED BY SECONDARY ALTERATION.



B. SUPERIOR LODGE, SUPERIOR MINE. PHOTOMICROGRAPH X 10. THIS SECTION SHOWS A VERY VESICULAR ROCK. AMYGDULES ARE CHIEFLY CALCITE AND CONTAIN LITTLE COPPER. NATIVE COPPER OCCURS ABUNDANTLY IN VERY SMALL PARTICLES IN THE DARK GROUND MASS.

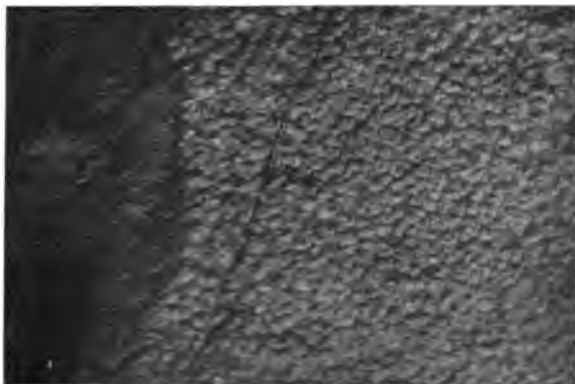




A. ALLOUEZ CONGLOMERATE, FRANKLIN  
JUNIOR MINE.



B. CALUMET CONGLOMERATE, TAMARACK MINE.



C. OPHITE, WEATHERED AND FRESH SURFACES.  
FRESH FRACTURE SURFACE AT LEFT.

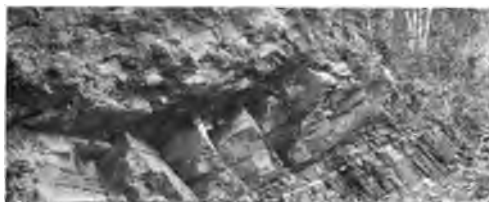




A. COPPER SHELLS FROM CALUMET CONGLOMERATE.



B. MASS COPPER, AHMEEK MINE.



C. SANDSTONE OVERLAIN BY TRAP, EAGLE  
RIVER.



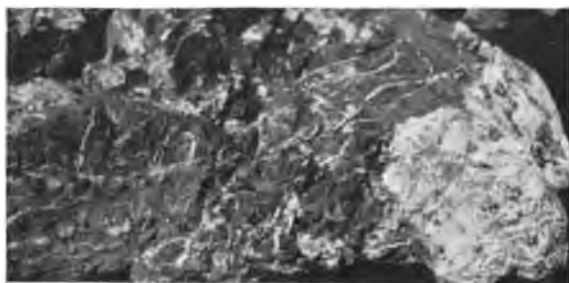
D. EXPOSURE OF TRAP BED, HOUGHTON.







A. DOMEYKITE VEIN. ISLE ROYALE MINE.



B. MASS COPPER AND FISSURED COUNTRY ROCK,  
AHMEEK MINE.



C. MASS COPPER, MICHIGAN SMELTER.





A. FOUNDATIONS OF THE TAMARACK RECRUSHING PLANT AND THE STAMP SAND IN TORCH LAKE.



B. THE LARGE DREDGE FOR HOISTING THE CALUMET AND HECLA STAMP SAND FROM TORCH LAKE.



The richer parts of lodes bear no definite relation to the present surface, their origin being quite independent of this surface.

(In many cases it has been found that the richest parts of lodes are neither near the surface nor at the lowest openings yet made. In the two lodes that have been mined at greatest depth, the Calumet conglomerate and the Pewabic amygdaloid, very rich ore occurred at depths of 1,000 to 3,000 feet.)

The ore now being mined from some of the lodes at great depth is much leaner than that which was mined some years ago nearer the surface; but the change in grade with depth is quite similar to change in grade laterally and there is no good reason to believe that it is due to deposition from descending solutions rather than to solutions moving in any other direction.\*

\*For discussion of methods of prospecting and developing the copper deposits and mining, concentrating, smelting, and refining the ores see *Mineral Resources of Michigan*, 1911, Publication 8, Geological Series 6, Michigan Geological and Biological Survey.

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**THE COPPER INDUSTRY IN 1914.**

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**WALTER E. HOPPER.**

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## GENERAL REVIEW.

The year 1914 will long be remembered as a most trying one for both operators and employees. The unusual conditions of labor and market caused most serious concern, and necessitated the most careful consideration of operations by the managers.

During the first four months of the year production was low and costs were high, due to the strike conditions and to the inexperienced labor underground. During the last five months of the year production was again greatly curtailed, owing to the European war. With a few exceptions, the total costs for the year were generally lower than those of the year 1913. The production was higher than the previous year but lower than the years immediately preceding 1913. According to the U. S. Geological Survey, the production of copper in Michigan during 1914 was 158,009,748 pounds, as compared with 155,715,286 in 1913. The average price received for copper sold, however, was much lower than in previous years, and the profits were, therefore, generally reduced. Very few dividends were paid during the year.

At the beginning of the year the copper country was still in the midst of the general strike called by the Western Federation of Miners July 23, 1913. In spite of this fact, however, most of the larger producers were operating, but on a smaller scale, and with inefficient labor underground. On January 6 there were about 8,724 men employed underground, as compared with about 13,514 before the strike.

Sunday, April 12, 1914, marked the official end of the long strike, when a general vote taken throughout the district expressed the desire of the majority of the men to return to work. The conclusion of the strike was received with general rejoicing throughout the copper country. There was a rush of men to the mines seeking their old positions, forces were increased as soon as possible, and the old spirit of satisfaction and good times again prevailed among the men. It would be impossible to even estimate the cost of the strike to the men, the mining companies, the state, the county, the townships, the villages and the workmen of the country. It is safe to say, that the figure would be between five and ten million dollars.

Following the end of the strike, a spirit of confidence and optimism existed throughout the district, and all efforts were made to make the year 1914 a more successful one than 1913, when higher costs and

lower production prevailed. Production was gradually increased; many of the mines were producing normally by May and June, and a maximum production was reached in July. Several of the properties in the exploration stage resumed operations in May.

Scarcity of suitable labor was keenly felt by the mining companies during the year 1912, and it has been estimated that when the strike was called, the various mines were operating with about 1,500 men short of normal force. However, immediately following the official end of the strike, the labor situation was much improved by a continuous influx of skilled labor. The unsettled conditions and curtailment of forces in the iron mines of Michigan and Minnesota sent hundreds of excellent miners to the copper districts. The mining companies took advantage of this opportunity, with the result that in the latter part of May, the mines were employing the largest working forces in the history of the district. This large working force naturally meant a great increase in the production of the mines and a corresponding reduction of costs.

When the general strike was called in 1913, the number of men employed on surface and underground at the various mines totaled about 14,250. On July 23, 1914, one year later, the same mines had in their employ about 16,505 men, showing an increase of about 2,255. The number of men employed at smaller exploration properties and those mines not included in the above, brought the total up to about 17,205. This was the largest number of men ever employed in the copper country. Not only was the total payroll higher than at any time previously in the history of the district, but the average individual pay-check was larger than ever before. New records of production were made at several mines, and all the companies were striving to set a new record for the production of refined copper before the end of the year.

This happy state of optimism and apparent prosperity was interrupted early in August by the European war. At first it was thought by a few optimists that a great demand for American copper for war purposes would be created by a general war. It was soon realized, however, that a European war would prevent the exporting of American copper, and when they considered the fact that over 50 per cent of the American output is exported, the operators realized that the war would have a serious effect on the American copper industry.

The general curtailment of production in the western districts was followed in Michigan by the closing of the Winona mine August 6. That this action was necessitated was deeply regretted by the people of the copper country, in view of the fact that successful experiments had recently been completed with a new regrinding machine and a

leaching process was also under consideration. The Mass mine at about the same time reduced its working force. With no market for the copper produced, curtailment was an absolute necessity in the Michigan district. The following day the Hancock mine, operating on borrowed capital, suspended all operations. This property had just reached a point where it was paying expenses. The Tamarack mine suspended all work at its two operating shafts.

A number of properties in the exploration and development stage were forced to suspend operations. These forced shut-downs were most unfortunate because, in many cases, they came at a time when the properties had reached the most hopeful stage of development.

With a large amount of refined copper on hand and practically no market, the Baltic, Champion and Trimountain mines of the Copper Range Consolidated, on August 15 went on half time schedule. The mines reopened September 1, and operated day and night shifts until September 15, when they closed again until October 1. On September 1 wages were reduced from eight to ten per cent, and the salaries of all officials at the mines and eastern offices were cut 25 per cent.

Beginning September 1, all the mines, mills and smelters of the Calumet and Hecla Mining Company went on a three-quarter time schedule, and the rate of wages existing immediately prior to May 1, 1912, when an increase of ten per cent was given the men, became effective. A reduction of 15 per cent in the pay of the officers and all those not affected by the increase of May 1, 1912, was made. A similar reduction was also made in the pay of all officers and employees of the eastern offices.

The Quincy Mining Company reduced the working force and put into effect a 12½ per cent reduction of wages and salaries of all employees and officials of the company.

The Mohawk and the Wolverine were the only mines in the district which continued to operate full time during the latter part of the year. This was because the product of these mines is used almost entirely by domestic consumers.

In view of the unsettled conditions of the copper market in this country, and the interruption of the company's business with foreign customers, the directors of the Calumet and Hecla Mining Company decided not to declare the usual quarterly dividend September 1. The Calumet and Hecla began paying dividends in 1871, and during the long period of 43 years, only once had the company found it necessary to pass its dividend. In May, 1884, because of the low price of copper and the delays in the sale of the mine products, no dividend was paid. Since 1901 the C. & H. has paid quarterly dividends and two payments had already been made in 1914. The general feeling of the people

of the copper country was, that under the conditions of reduced wages and half time, the passing of the dividend was the only fair and proper thing to do.

With the closing of the stock exchanges in Boston and New York, the local brokerage offices in Houghton and Calumet were closed.

The first of September the American production was being curtailed about 45 per cent. Domestic buying was active and about half the normal amount of copper was being exported, in spite of the war conditions. The production of copper was about equal to the consumption. Exports to England were chiefly the filling of old contracts or shipments on consignment.

Difficulties encountered in shipping copper resulted in a decrease of exports. The interception of vessels for Italy and Scandinavia, and the seizures of copper cargoes by Great Britain the latter part of October resulted in very light shipments and a marked falling off in copper exports. The Copper Country Commercial Club sent a formal letter of protest against this action of Great Britain to Secretary Bryan at Washington. Copper producers and commercial clubs in all copper producing districts in the United States also sent similar letters of protest. The total amount of copper seized and detained by Great Britain was about 45,000,000 pounds.

The curtailment of production at the mines and the refineries, the decrease in domestic demand and the difficulty of exportation had a marked effect upon the copper market and the price of copper, which in turn, determines profit and loss in the Michigan district. The copper market opened in January at 14.55 cents. About the middle of February the price stood at 14.65 cents, the highest point of the year. The last of July the price dropped to about 12½ cents and in August the market went to pieces. On November 1 the price was about 11.15 cents but a buying movement carried it up to about 13.2 in December. The market closed in New York at the end of the year at about 12.70 cents.

The price received by the Calumet and Hecla Mining Company varied from 12 cents to 15¼ cents. On December 31 it was about 13¾ cents.

During the last two months in the year there was an increase in the business and buying of the domestic manufacturers which resulted in an unusual and unexpected domestic demand for refined copper at the Michigan smelters. About the middle of November the largest shipment of refined copper ever made from the Michigan district was taken to Buffalo by the Mutual Transit Co.'s steamer North Star. The cargo totaled 9,000,000 pounds, and included consignments from the Calumet and Hecla dock on Torch Lake, the smelter dock at Dollar

Bay and the Quincy and Copper Range docks on Portage Lake. With the close of navigation on the Great Lakes, the copper country docks were cleared of all copper on hand. The last shipments of the season were made December 1, when two large cargoes left for Buffalo. All available metal was shipped and the clean-up during November was most unusual. The vessels carried copper that was smelted even on the day of sailing.

Full wire service with Boston, New York and Chicago was resumed early in December when the Boston stock exchange reopened for business.

During the latter part of the year, the copper country was visited by several serious disasters. On December 18 one of the boilers at the No. 3 shaft of the North Kearsarge mine of the Osceola Consolidated exploded. The boiler house was almost completely wrecked, the fireman killed and the No. 3 shaft put out of commission. Several weeks previous the boiler house and compressor plant at the Superior mine were destroyed by fire.

Early Christmas morning the stamp-mill of the Isle Royale Mining Co., on Portage Lake, one mile east of Houghton, was completely destroyed by fire. The loss will exceed the insurance of \$100,000 by from \$30,000 to \$50,000. The whole plant, with the exception of the carpenter shop, boiler house and office, was burned to the ground. Christmas day the mill was a skeleton mass of twisted pipe and machinery. As is characteristic of the Calumet and Hecla management, removal of the ruins to clear the site for the erection of the new mill was begun the following day. The advantage to the Isle Royale of being under the management of the C. & H. was clearly shown by the fact, that while the mill was completely out of commission, not an hour's time was lost at the mine. The Isle Royale ore was immediately shipped to the Centennial-Allouez mill at Point Mills.

#### CONSTRUCTION WORK.

Construction work during the year 1914 was restricted practically to the period from May to August. Strike conditions existed during the first few months and costs were high. The unusual conditions of the copper market, owing to the European war, made it necessary to reduce expenses as much as possible and early in August all construction was discontinued throughout the district.

Work at the White Pine was continued and \$195,929.84 was expended for construction at the mine. For details of this work see report of White Pine Copper Co.

Ground was broken for the foundations of the recrushing plant at

the Tamarack mill in the summer. The foundations were completed and the steel work erected before the end of the year.

The Osceola Consolidated expended \$21,109.17 for new construction at all branches. Of this amount about \$6,700 was for stamp-mill reconstruction, including elevation of railroad tracks and enlargement of boiler plant. At the Osceola branch \$6,765.97 was expended for the erection of a new rock-house at No. 3 shaft, the rebuilding of the boiler house and grading for railroad tracks to the rock and boiler houses. At the North Kearsarge branch \$7,627.79 was expended. Of this amount \$1,667.50 was for the equipment of No. 1 rock-house and collar-house. The change-house at No. 1 shaft was practically rebuilt and new equipment was installed at the pumping station at Kearsarge dam.

The Isle Royale paid out \$34,858.55 in preparation for reopening No. 1 shaft, in building a boiler house at No. 5 shaft, and in installing an electrically driven plunger pump at the Huron dam pumping station.

Ahmeek expended \$229,663.45 for construction, which included the installation of a low-pressure steam turbine, 46 Wilfley tables, eight Hardinge mills and foundations for two stamps at the stamp-mill.

The Calumet and Hecla continued the work in the new recrushing plant; the installation of the machinery in the large dredge was finished, and ground was broken for the large leaching plant.

The Copper Range Consolidated continued the improvements at the stamp-mills and underground, and the improvements at the Centennial-Allouez mill were practically finished.

Mohawk spent for construction \$15,155.34. Several improvements were made at the stamp-mill and additional equipment installed at the shafts and rock-houses.

At the Quincy construction, equipment and betterment expense was maintained as low as possible. During the year \$57,190.41 was spent for the recovery of the shafts and levels damaged by air blasts and \$21,487.19 was expended in work towards preventing these damages.

#### MINE CASUALTIES.

The report of the Houghton county mine inspector showed a total of 29 casualties for the year ending September 30, 1914. This county includes, besides numerous properties being developed, the mines of the Calumet & Hecla, Copper Range Consolidated, Quincy, Winona, Superior, Isle Royale, Hancock, Franklin, Osceola, Kearsarge and Centennial. The largest number of casualties was four at the Baltic. The reports of the inspector since 1888 to date show that the highest percentage of accidents was in 1895, when, with 7,249 men employed,

there were 44 fatalities. During that year, however, 30 men were suffocated at the Osceola. The percentage for 1914 was 0.0022 with 12,954 men employed. The only year which shows a better percentage is 1899, when, with 13,057 men employed, 27 accidents occurred, giving a percentage of 0.0021. The report of the inspector of Keweenaw county showed four mine fatalities during the year.

#### SANITARY CONDITIONS.

An inspection of the sanitary conditions of the communities of the copper country by Robert Olsen and Joseph Bolton, of the U. S. Public Health Service, was completed about the first of November. Almost perfect conditions were found in the mining centers of the district, and there is no doubt that the living conditions in the Michigan copper country are far better than in the average mining district.

#### THE COPPER HANDBOOK.

"The Copper Handbook" will no longer be published in the Michigan copper districts. This well known publication on copper was founded in 1900 by the late Horace J. Stevens, of Houghton, and was published annually by him until his death in April, 1912. About a year later, rights of the book were sold to Walter Harvey Weed. Mr. Weed, as owner and editor, opened an office in Houghton and published the 1914 edition. It was feared at the time of the sale that Mr. Weed would not maintain an office in Houghton for any length of time. However, the news of the removal of the publication office to New York was received with much regret by the people of the copper country. Mr. Weed desired to handle all his business interests from one New York office, and the Houghton office of "The Copper Handbook" was closed about December 1.

#### THE DOUGLASS HOUGHTON MEMORIAL.

Upon a hill overlooking the waters of Lake Superior where they touch the shore of Keweenaw Point at Eagle River, there now stands an impressive and permanent monument to the memory of Douglass Houghton, scientist, explorer and Michigan's first State Geologist. The monument, erected through the efforts of the Keweenaw Historical Society, was dedicated October 10, 1914. It stands upon a triangular piece of land deeded to the Keweenaw Historical Society by the Cliff Mining Co. The base of the monument is composed of about 175 pieces of characteristic rocks of the copper and iron country. Upon the base rests a large mass of the Keweenawan greenstone, imbedded



in which is a tablet, made of Lake Superior copper, with a relief reproduction of the painting of Houghton by Bradish. Houghton is seen standing on a rocky shore with a geological pick in his hand and his dog Meme at his feet.

DETAILS OF OPERATIONS OF THE MINING COMPANIES IN 1914.

. Ahmeek Mining Company.

Mine location: Ahmeek, Keweenaw county.

General Manager: James MacNaughton.

Superintendent: S. Russell Smith.

Controlled by the Calumet & Hecla Mining Co.

During the first few months of the year, the Ahmeek was gradually recovering from the effects of the strike. Early in August, owing to the European war, all extraordinary work was stopped and expenses were cut to the lowest possible point. For details of the general curtailment of September 1, see report of Calumet & Hecla Mining Co.

No sinking was done in any of the four shafts during the year 1914. All openings in No. 1 shaft have shown ground of average quality. To the south of the shaft there is a disturbed area due to a mohawkite seam, but President Agassiz reports that the ground opened between this and the North Kearsarge and Allouez boundaries is looking very well.

At the No. 2 shaft drift stoping was started about the middle of March. All openings show average values. President Agassiz reports that the mass copper fissure north of the shaft has been opened up for a distance of 500 feet on the 10th level, 262 feet on the 11th level, 211 feet on the 13th level, 212 feet on the 14th level and 27 feet on the 15th level, and has been reached on the 17th level, where it is as rich as at any point exposed before.

At shafts Nos. 3 and 4 construction was practically completed in May and the new equipment went into operation June 1. President Agassiz reports that all openings in both shafts show ground of average quality for this end of the mine. All operations were suspended August 6.

In shafts Nos. 2 and 3 mules are being used for tramming with very satisfactory results.

At the stamp-mill a low pressure steam turbine was put in place and completed except for electric connections. All floors and foundations for two stamps were finished; 46 Wilfley tables were installed on the main floor; eight of the 12 Hardinge conical tube mills and the anvil and stamp mortar for one of the two steam stamps were installed. All outside launders, trestles, mineral tracks, etc., were completed.

All work on this addition and its equipment, however, was discontinued on August 6th.

During the year 590,694 tons of rock was hoisted and only 175 tons (0.03 per cent) was discarded in the rock-house. The company was able to pay \$200,000 in dividends.

#### Algomah Mining Company.

Mine location: Lake Mine, Ontonagon county.

Superintendent: Thomas Bennett.

No mining was done on the property during the year 1914. A shipment of 74,560 pounds of selected ore, taken out during the sinking of the shaft, was made to the Michigan Smelter. No difficulty was found in treating it in the regular furnaces and the shipment yielded 18 per cent copper. Shaft sinking will be resumed in the spring of 1915.

#### Allouez Mining Company.

Mine location: Allouez, Keweenaw county.

General Manager: James MacNaughton.

Superintendent: F. W. Ridley.

Controlled by the Calumet & Hecla Mining Co.

During the first four months of the year production was low and costs were high, due to the strike conditions and to the inexperienced labor underground. Production, however, was gradually increased, reaching a maximum in July. For general curtailment of operations due to European war, see report of Calumet & Hecla Mining Co.

Openings in the upper levels of No. 1 shaft have been fully up to the average but the lower levels have developed ground somewhat leaner. Developments in No. 2 shaft have been up to average quality. Very little work was done on surface during the year.

Allouez produced during the year 6,056,548 pounds of refined copper from 354,457 tons of ore treated, an average of 17.09 pounds per ton. Assets were increased during the year by \$114,530.43.

#### Baltic Mining Company.

Mine location: Baltic, Houghton county.

General Manager: F. W. Denton.

Superintendent: Albert Mendelsohn.

Controlled by the Copper Range Consolidated Co.

Normal conditions of operation were reached in June. Two months of full production were followed by another reduction of output caused by the European war. Beginning with August, all employees and

departments were put on half time schedule, working for half of each month and shutting down completely for the other half. During the time when the mine was not operating, necessary repair work was done in the shafts.

Improvement was found in the ground opened at the bottom of No. 3 shaft. The developments in No. 2 shaft are in good ground. Considerable stoping ground was found in explorations on the west lode at No. 5. shaft.

The use of waste stamp sand for filling stopes in the mine was begun in August, and during the year 17,670 yards was run into the stopes tributary to No. 2 shaft. This practice has been found very successful, not only in reducing the cost of filling stopes, but also in permitting more rapid and systematic work.

Baltic produced 7,001,945 pounds of refined copper at a yield of 21.59 pounds per ton stamped. The profit per pound was 2.21 cents.

#### Calumet & Hecla Mining Company.

Mine location: Calumet, Houghton county.

General Manager: James MacNaughton.

Superintendent: John Knox.

During the first four months of the year production was low and costs were high, due to the strike conditions and to inexperienced labor underground. Production, however, was gradually increased, reaching a maximum in July. The unusual conditions of the copper market due to the European war, and the uncertainty of being able to sell the copper produced, made it necessary for the company to curtail production and to reduce expenses as much as possible. On September 1, wages were reduced about ten per cent, or to the rates existing previous to May, 1912, salaries of all officers and employes in both the mine and eastern offices were reduced 15 per cent, and the mine operated on a three-quarters time basis.

During the year 1914 there was produced 53,691,562 pounds of copper from 2,592,462 tons of ore treated, an average of 20.70 pounds per ton. The total cost per pound was 11.35 cents and the price received for copper sold was 14.01 cents per pound.

The conglomerate lode yielded 37,996,045 pounds of copper, an average of 26.38 pounds per ton, at a total cost per pound of 10.42 cents. About 35 drills are at work removing shaft pillars and cleaning up arches and backs of old stopes. Little change has been found in the character of the openings in the Hecla and South Hecla branches.

The openings on the Osceola lode show about the same grade of ore

as in the year 1913 and the product secured from foot wall stopes was about 34 per cent of the entire tonnage.

The No. 21 shaft operating on the Kearsarge lode, was closed down July 23, 1913 and no work has been done on this lode since that date.

At the Manitou-Frontenac Branch the only work done during the year was the diamond drilling of 31 feet on hole No. 27, which completed the cross section on the northwest quarter of Section 17, T. 57 N, R. 31 W. No values were developed.

At the St. Louis branch no work of any kind was done during 1914.

At the stamp-mills 16 of the tube mills in the new No. 2 recrushing plant were started in July. All further work on the installation of the equipment was stopped August 1. An interesting comparison of the efficiency and cost of operating the new No. 2 recrushing plant with the old No. 1 plant is as follows:

	No. 1 Plant.	No. 2 Plant.	Both Plants.
Tons coarse tailings crushed.....	351,929	75,630	427,559
Pounds per ton in material treated.....	11.52	11.84	11.58
Pounds copper saved per ton.....	3.74	4.59	3.89
Pounds copper produced.....	1,316,704	347,363	1,664,067
Cost per pound, excluding smelting and selling.....	7.38c	5.66c	7.02c

The installation of the machinery in the large dredge was finished, the dredge was tested and the management reports that it met the guarantees and requirements fully. Plans were completed for a large leaching plant to retreat the tailings from the recrushing plants; ground was broken and contracts for the steel for building and tanks were let, but on account of the unusual copper market all work was discontinued in August.

All operations have been discontinued at the Buffalo works and the entire product of the mine is now being smelted at the Hubbell works. The new electrolytic plant is working at full capacity of about 65,000,000 pounds per year.

During the year 1914 the C. & H. paid only two dividends, amounting to \$1,000,000 and received from the Ahmeek and Osceola companies in dividends \$245,322. Dividends received exceeded interest paid on C. & H. notes by \$78,962. The expenditures of the aid fund during the year amounted to \$36,016.48.

**Centennial Copper Mining Company.**

Mine location: Calumet, Houghton county.

General Manager: James MacNaughton.

Superintendent: F. W. Ridley.

Controlled by the Calumet & Hecla Mining Co.

The operations for the Centennial for the year 1914 show a decrease in assets for the year of \$3,213.09.

No development or stoping was done in the vicinity of No. 1 shaft. Openings to the north of No. 2 shaft showed average ground for the first nine months of the year but were lean the latter part of the year, with the exception of the 34th drift.

This decrease in copper contents and the unusual condition of the market made it impossible to operate at a profit and further reduction in costs was necessary. The first of December a system of full time work with lower wages was put in force. This plan meant larger monthly earnings to the men and a reduction of costs to the company. The Centennial suffered the same curtailment September 1 as the other C. & H. subsidiary companies. For details see report of Calumet & Hecla Mining Co.

During the year 2,287,130 pounds of refined copper was produced from 138,136 tons of ore treated, an average of 16.56 pounds per ton. The total cost per pound of refined copper was 12.56 and the price received was 12.111 cents.

**Champion Copper Company.**

Mine location: Painesdale, Houghton county.

General Manager: F. W. Denton.

Controlled by Copper Range Consolidated Company and St. Mary's Mineral Land Company.

During the first part of the year there was a reduction in output due to the strike. From August in the end of the year the mine produced only half time. Considerable repair work was done in the shafts during the shut-downs.

Fire destroyed one of the old wooden change-houses located near "D" shaft. General manager Denton states that plans have been made for a new, large, modern, fireproof building which will accommodate both "D" and "E" shafts.

A special spur track and concrete loading bin were constructed at the mill to facilitate collecting and loading waste stamp sand. During the year, 84,090 cubic yards of stamp sand was run into the mine for filling stopes. Underground electric locomotives are proving profit-

able. Two more were added during the year and several more will be put into service in 1915.

Development was far ahead of production and openings were not pushed at the usual rate during the year. No shaft sinking was done. The number of pounds of refined copper produced was 15,807,206, and the yield of copper per ton stamped was 25.71 pounds. The total cost per pound was 9.21 cents and the profit per pound 4.17 cents.

#### Cliff Mining Company.

Location of property: Keweenaw county.

General Manager: James MacNaughton.

Controlled by the Calumet & Hecla Mining Co.

Balance of assets was reduced by \$9,938.22 during 1914.

No work was done at the temporary shaft. Three drill holes were put down in order to complete the exploration from the Kearsarge amygdaloid to the most easterly part of the company's lands. In two holes the rock was so badly broken that definite correlation with other holes was impossible. The third hole at a depth of 638 feet reached the boundary of the property and was continued to a depth of 1,155 feet by the Tamarack Mining Co. on its property. President Agassiz reports that very little copper was disclosed by this work.

#### Contact Copper Company.

Location of property: Elm River, Houghton county.

Superintendent: George S. Goodale.

Owing to strike conditions in Michigan, general business conditions everywhere, and the European war, only a small amount was paid on account of the assessment of 50 cents per share called in April, 1914. Since no contract for diamond drilling could be safely made until the treasury was sufficiently supplied with funds to warrant it, no work was done on the property during the year 1914.

Superintendent G. S. Goodale states that practically all of the 2,360 acres of the property lie within the copper-bearing zone of Houghton county. He further states that "the property possesses a maximum distance along the strike of the formations of nearly 17,000 feet and a horizontal transverse distance, at right angles to the strike, of nearly 12,000 feet. The formations, so far as determined, have an average dip of about 60 degrees from the horizontal, which affords a mineral acreage of about twice the surface acreage. The property includes the horizons of practically all the mineralized formations of the district lying between the eastern sandstone and the so-called Ashbed series of Keweenaw Point."

President H. F. Fay points out to the stockholders that additional systematic drilling should be done on certain portions of the lands which have already been partially examined. Between the depths of 1,590 feet and 1,621 feet, Contact drill hole No. 5 disclosed a copper-bearing amygdaloid, lying between two conglomerates, which corresponds approximately with the indicated position of the extension of the so-called No. 8 Wyandot lode. This extension should pass through the eastern part of the Contact lands and would underlie the whole property, thus making available a maximum tonnage favorable for commercial exploitation. It is intended to determine the value of this formation by drilling one or more additional holes parallel to the No. 5 drill hole. This, however, cannot be undertaken until the stockholders have paid their assessment in sufficient amounts to warrant contracting for the work. When work was suspended for lack of funds, there remained over 3,000 feet of drilling to complete the first cross-section of the property.

President Fay states that through a timber contract the company will be relieved from paying most of its taxes in Michigan for the present. There is also a considerable stock of machinery and mining supplies in possession of the company, which can be sold whenever opportunity offers or will be available when active mining operations are undertaken.

#### Copper Range Consolidated Company.

Mine office: Painesdale, Houghton county.

General Manager: F. W. Denton.

Controls Copper Range Co., Baltic Mining Co., Trimountain Mining Co., and Atlantic Mining Co., and owns half of Champion Copper Co.

The production and profits for 1914 were far below the normal. The effects of the strike greatly reduced production during the first part of the year. Normal output was not reached until July. The output increased from a yearly rate of 17,086,309 pounds in January to 30,792,612 pounds in July. The European war again necessitated a reduction of production which was effected by working the first half of each month and remaining idle for the last half. The Copper Range Consolidated was one of the first companies to curtail production, the first shut-down occurring August 15th. The August output was one-half that of July and this curtailment continued for the remainder of the year.

When work was resumed September 1 wages were reduced from eight to ten per cent; the salaries of all officials at the mines and eastern offices were cut 25 per cent and all these reductions continued through the remainder of the year. By this method the output was reduced

without disturbance to the organization, and operations were carried on normally during the working periods. The cost of production, however, was greatly increased by the expense of maintenance and repair work during the idle periods. All expenditures are charged to cost of copper.

On January 1, 1915, the Copper Range Consolidated opened a sales office at 32 Broadway, N. Y., with Mr. W. Parsons Todd as manager of copper sales. Since 1906 the United Metals Selling Co., of New York, had acted as selling agent for the company. The selling commission was one per cent and the average yearly commission paid was \$55,000. It was felt that the company could handle the sale of its product direct to the trade at less cost and at the same time could get a closer touch with the requirements of its customers.

The use of raises in mining has been continued and the use of stamp sand for filling in the mines has increased with profitable results. The number of electric locomotives for underground tramping was increased. President Paine states that "the physical conditions at all the mines are good and assure a successful and profitable future. Due to various improvements in underground work and in milling, it is expected that the yield of copper per ton will be materially higher in the future, and if this expectation is realized, it will result in a lower cost per pound."

#### Franklin Mining Company.

Mine location: Demmon, Houghton county.

Superintendent: Enoch Henderson.

The only production during the year 1914 came from the test stamping of 7,324 tons of rock taken from the new openings on the Allouez conglomerate at the 32d level. President Edwards states that the results of this test, taken in connection with the general appearance of the openings since made, warrant the belief that the lode can be mined at a profit. Regular production will probably begin about the middle of May, 1915.

A small compressor was installed in No. 1 shaft-house and other changes made to permit the economical operation of a number of drills. One drill was put into operation the latter part of January in the foot wall cross-cut on the 32d level. Other drills were added until six were in operation. The crosscut on the 32d level was advanced 927 feet easterly to the first amygdaloid under the Houghton conglomerate. Besides the Allouez conglomerate and the Houghton conglomerate, six amygdaloid beds were cut in this crosscut. Superintendent Henderson states that three of these amygdaloids were barren, two carried copper in small quantities and one showed mineral and vein



matter worthy of further development. The Calumet & Hecla conglomerate should be reached in April, 1915.

Drifting on the Allouez conglomerate at the 32d level was begun about the middle of March. A great deal of interest was shown in the openings in the Allouez conglomerate which were made for the purpose of determining the value of the lode as a whole, without selection in mining or discard from the rock broken. The drifts were cut as wide as the hanging would permit and for the first four mill-runs, all rock broken was sent to the mill. A small quantity of rock was discarded in the rock-house from the last mill-run. Superintendent Henderson reports the results of stamping as follows:

	Tons rock.	Pounds dry mineral.	Assay.	Pounds copper.	Pounds copper per ton.
April 5, 1914.....	906	26,220	58.35	15,300	16.89
April 25, 1914.....	538	14,340	55.77	7,072	13.14
May 10, 1914.....	1,138	22,592	54.38	12,285	10.79
June 9, 1914.....	2,195	48,985	46.90	22,978	10.46
August 26, 1914.....	2,547	63,807	55.87	35,650	14.00
	7,324	175,944	.....	93,283	12.73

Tailings averaged six pounds per ton.

#### Hancock Consolidated Mining Company.

Mine location: Hancock, Houghton county.

General Manager: John L. Harris.

The Hancock, operating on borrowed money, was greatly retarded in development work by the strike and the European war. During the year a total of 2,300 feet of drifting was done at six levels on veins intersected at depth in the No. 2 shaft. Stoping was done at four levels on the No. 3 lode, at three levels on the No. 4 lode, at two levels on the No. 8 lode and at two levels on the No. 9 lode.

The rock from this development work was stamped by The Lake Milling, Smelting & Refining Co., and yielded 488,678 pounds of refined copper which was sold at 13.389 cents per pound.

During the year the directors found it necessary, in order to carry on operations, to borrow \$164,000 from eastern bankers.

With the exception of keeping the mine free of water, all mining operations were suspended August 8th for the balance of the year. General Manager Harris reports that the physical condition of the property is such that mining operations can be resumed at any time.

## Houghton Copper Company.

Mine location: North of the Superior Mine, Houghton county.

Superintendent: R. R. Seeber.

Operations were resumed with one shift on January 13th. The sinking of the winze below the 820 foot level was continued for a depth of 102 feet. The 620 foot level was extended north 383 feet and showed an occasional bunch of good copper ground but generally was rather poor. A 70 foot crosscut was driven to the hanging. The 1,020 foot level was extended 397 feet to the south and 334 feet to the north of the winze, and superintendent Seeber reports that some very good copper ground was encountered on both sides.

A railroad spur will be run to the property in the spring which will enable a mill test to be made of the rock pile of 7,500 tons which has accumulated from the development work. All operations were discontinued on September 15th.

## Indiana Mining Company.

Mine location: Indiana, Ontonagon county.

Superintendent: Thomas Bennett.

Work was resumed in May. The shaft was unwatered to the 600 foot level and all the work of the year was done on that level. The purpose of the work was to determine the extent and character of the felsite mass encountered there, with the hope that this data might lead to the definite location of the rich felsite cut by No. 2 drill hole at 1,450 feet. A total of 1,152 feet of drifting and crosscutting was done during the year.

By means of drifts, crosscuts, a raise and a winze, it was found that the felsite mass at the 600 foot level lies in the form of a wedge with its apex 30 feet northwest of the shaft and its eastern and southern boundaries still undetermined.

The thickness of the felsite was determined by two crosscuts from the drift in the western contact. The first crosscut, 40 feet south of the shaft, shows the felsite 65 feet thick; the second crosscut, 120 feet south of the shaft, shows the felsite 115 feet thick; a third crosscut, 220 feet south of the shaft, was driven east into the felsite 160 feet, and is still in felsite.

President Edwards reports that in the first and second crosscuts a wide zone of felsite was encountered heavily mineralized with carbonate of copper. Average assays of 60 feet in the second crosscut gave 13 pounds of copper to the ton, and for a width of ten feet gave 19 pounds of copper to the ton. It is the intention of the management to have a thorough geological examination made.

Work is now being confined to locating No. 2 drill hole at the 600 foot level by means of a crosscut and chamber. This hole will be surveyed to the bottom with the hope of locating positively the position of the rich felsite found by the drill at 1,450 feet.

Isle Royale Copper Company.

Mine location: Houghton, Houghton county.

General Manager, James MacNaughton.

Superintendent: James E. Richards.

Controlled by the Calumet & Hecla Mining Co.

Production was very much restricted by scarcity of labor during the first third of the year and it was not until June that production reached normal. As a Calumet & Hecla subsidiary, Isle Royale suffered the same general curtailment on September 1st as the Calumet & Hecla. For details see report of Calumet & Hecla Mining Co.

The operations for 1914 show an increase in assets of \$24,374.12. From 474,349 tons of ore treated, 6,601,235 pounds of refined copper was produced, an average of 13.9 pounds per ton. The total cost per pound refined copper was 13.05 cents and the price received was 13.16 cents per pound.

In May retimbering of the old No. 1 shaft was started. The timber in this shaft was destroyed by fire on December 18, 1903 and since that time no work has been done in the vicinity. The shaft was started in the Isle Royale lode and is bottomed at 1,614 feet from surface. The greater part of the production was mined from the west lode by means of crosscuts on the 9th to the 15th levels. There is broken ore in many of the stopes and some of it can be recovered.

The management decided to reopen the No. 1 shaft and to resume sinking in order to explore and mine the West lode, especially in the Montezuma ground. In August the shaft had been retimbered to 15 feet below the 8th level when all work was discontinued owing to the European war.

Practically all of the ground opened by drifts south of the No. 2 shaft on the Isle Royale lode was of inferior quality. The water in the old Huron mine was lowered to a point below the 14th level of this shaft and the level was extended to the Huron workings.

About 50 per cent of the ground opened by drifts on the West lode to the north of No. 2 shaft was of stoping quality. The drifts on the 28th and 29th levels passed through the corner of the Montezuma property for several hundred feet and both showed average copper ground. At the Nos. 4, 5 and 6 shafts a total of 6,960 feet of drifting was done, about 70 per cent of which was in copper ground of stoping

quality. No work was done at No. 7 shaft but the management is contemplating the resumption of work at this point.

For transporting 191,597 tons of Superior ore at seven cents a ton, \$13,411.79 was received. This reduced the cost of transporting Isle Royale ore over its own tracks to 3.83 cents per ton.

On the night of December 24th the stamp-mill was completely destroyed by fire. The mill and its contents were insured for \$100,000, but the loss will exceed the insurance by from \$30,000 to \$50,000. The management hopes to have the new mill ready for operation by June 1, 1915. Until the new mill is finished, Isle Royale ore will be stamped at the Centennial-Allouez and Tamarack mills.

#### Keweenaw Copper Company.

Mine location: Near Phoenix, Keweenaw county.

General Manager: W. J. Uren.

This company owns nearly all of the outstanding stock of the Phoenix Consolidated Copper Company, over five-sixths of the outstanding stock of the Meadow Mining Company, and a majority of the outstanding stock of the Humboldt Copper Company. The shares in above companies were obtained by purchase or by exchange for shares of the Keweenaw Copper Co. The mineral lands of these companies are contiguous and it is essential that these lands be explored and developed by the organization to secure economical results.

Diamond drilling along the strike of the Ashbed lode was continued until May 28, 1914. President T. F. Cole reports that enough advance information to enable the management to concentrate their efforts toward the development of a mine was secured.

No work was done on the lands of the Humboldt Copper Company during 1914. For other exploratory work see reports of Phoenix Consolidated Copper Company and Meadow Mining Company.

#### Lake Milling, Smelting & Refining Company.

Seven of the eight boilers in the new boiler house are in commission. The wash of No. 1 head is being remodeled, and 1,000 feet of tailing-laundry was completed for heads Nos. 2 and 3.

Because of the increase in production of Superior, Isle Royale, Allouez and Centennial, stamping facilities at the mill became congested in May. The remodeling of the two heads in the little Tamarack mill was completed in June and some Allouez and Centennial ore was sent to that mill. When the Isle Royale mill was destroyed late in December all the Isle Royale ore was sent to the Point mill. This necessitated another change by which the Allouez ore was handled in the

little Tamarack mill and the Centennial product by the Osceola Consolidated Mining Co. By this arrangement the Allouez and Centennial companies saved in freight rate six cents a ton.

During the year 9,685 tons were stamped for the Winona Copper Company and 4,777 tons for the Franklin Mining Co.

On September 1 the mill went on a three-quarters time schedule and a reduction in wages corresponding to that of the Calumet & Hecla mines went into effect.

#### La Salle Copper Company.

Mine location: South of Osceola, Houghton county.

General Manager: James MacNaughton.

Controlled by the Calumet & Hecla Mining Company.

During the year 1914 the La Salle produced 540,731 pounds of refined copper from 45,509 tons of ore treated, an average of 11.88 pounds per ton. The price received for copper sold was 12.797 cents and the balance of assets was further reduced by \$48,668.30.

At No. 1 shaft some stoping was done and a larger hoist was about to be installed when the mine was closed down.

The operations at No. 2 shaft consisted of stoping on the 12th level, drifting on levels below the 12th and sinking the shaft. The management reports that the openings were generally in fair copper ground on the north side of the shaft and at the 17th, or lowest level, copper ground was beginning to show on the south side also.

The mine was closed down early in August on account of the European war. Pumping has been continued and the water has not been allowed to rise above the 13th level in either shaft. The management has planned to resume operations in the early summer of 1915.

#### Mass Consolidated Mining Company.

Mine location: Mass, Ontonagon county.

Superintendent: E. W. Walker.

Operations were resumed on a small scale the latter part of February. Normal operating conditions were reached in May. The low price of copper caused by the European war made it impossible for the Mass to operate successfully. Since expenses would be greater if the mine were closed than the loss when running, the management decided to continue operations, retain their organization and give work to their employees.

More development work was done during 1914 than in 1913 and an appreciable amount has been added to the ore reserves. The estimated "Butler" ore reserves December 31, 1913 were 824,196 tons; reserves

added during 1914 were 439,179 tons, making a total of 1,263,375 tons. During 1914, 151,620 tons were extracted, leaving estimated "Butler" ore reserves December 31, 1914, 1,111,755 tons.

Superintendent Walker states that so far it has been impossible to estimate the ore reserves in the Evergreen and other lodes with any degree of accuracy, but that the Evergreen has and will continue to produce a considerable tonnage of stamp rock in addition to a large part of the mass copper produced by the mine. The Evergreen, Ogima and Knowlton lodes produced in 1914, 57,734 tons of ore.

President Linnell reports that during the past few years the company has been putting excessive expenditures into development but that from now on mining will be done on a larger scale and the proportional expense of development cost will be considerably less per pound of copper produced. The president further reports that the "Butler" lode in both "B" and "C" shafts is increasing in width with depth and is showing a material increase in copper contents.

#### Mayflower Mining Company.

Location of property: East of Kearsarge and Wolverine mines, Houghton county.

Superintendent: George S. Goodale.

Further exploration of the property by diamond drilling was continued during the year 1914. Two diamond drills were used in holes Nos. 35 to 41 inclusive, and a total of 10,304 feet was drilled during the year. The overburden in these holes varies from 5 to 28 feet.

Holes 36 to 40 are in the northeast quarter of section 8 and were drilled to extend the investigations northward, along the strike of the formations. Holes 35, 39 and 41 are in the southwest quarter of the same section and were drilled to explore the ground to the west of the earlier drilling.

Superintendent Goodale states that holes 34 and 37, which make up a transverse vertical section across the formations, indicate a much disturbed condition of the rocks due to faulting and crushing. Holes 36, 38 and 40 show that the lower beds have undergone repeated and in some places, pronounced disturbance. Holes 35 and 39 indicate faulting of considerable magnitude, but do not show the generally unfavorable conditions found in the northern part of the property. The last hole was located farther west and should intersect the Mayflower lode much deeper than encountered elsewhere.

### Meadow Mining Company.

Location of property: Adjoins Phoenix Consolidated Copper Co., Keweenaw county.

Three diamond drill holes were bored through a portion of the hanging wall and across the Ashbed lode.

President Thomas Hoatson reports that two of these holes intersected the copper-bearing part of the lode at 489 feet and 364 feet respectively from the surface. The third hole cut the same formation at 713 feet from surface and disclosed vein matter of good width with good values in both the upper and lower portions of the amygdaloidal flow.

### Mohawk Mining Company.

Mine location: Mohawk, Keweenaw county.

Superintendent: Theo. Dengler.

During the year 1914 Mohawk produced 11,094,859 pounds of refined copper at a total cost per pound of 8.23 cents. A dividend of \$100,000 was paid August 15th, and the strike expense for the year was \$23,685.77.

Following the strike, limited operations were begun in December, 1913 but it was not until May, 1914 that normal production was started. The Mohawk continued normal production throughout the year and was one of the two producing mines in the district which did not curtail operations because of the war.

Mohawk is now operating six shafts. The mine is equipped with 90 "Ingersoll Leyner" drilling machines and also with jack hammers and stoppers. It is the intention of the management to close down permanently No. 3 shaft. Blocks, pillars and foot rock of value that cannot, without much extra expense, be reached in later years from No. 2 and No. 4 shafts are being removed. Considerable mass and heavy copper were obtained during this work. Test crosscuts into the foot and hanging on the 7th level did not show any values.

There was expended for construction \$15,155.34. Plans for a new rock-house at No. 5 shaft are now under way. At the stamp-mill considerable expense was incurred in keeping the intake cleared from ice and debris. In order to maintain an open channel for slimes through the stamp sand, a reinforced concrete tunnel, 314 feet long, three feet wide, and five and a half feet high inside with 330 feet of retaining walls was constructed. Four additional Wilfley concentrating tables were installed in the mill to handle slimes.

### Naumkeag Copper Company.

Mine Location: Houghton, Houghton county.

Superintendent: Sidney S. Lang.

Exploration was continued by means of crosscuts and drifts and some fairly good copper was found in several of the openings.

At the beginning of the year the Dakotah Heights adit had been driven east a distance of 245 feet and had encountered a lode which contained copper, and which was presumed to be the foot wall bed of the Quincy-Pewabic series. An electrically driven compressor and an electrically operated hoist were installed at the mouth of the adit to raise the rock sufficiently high to form a dump.

Drifting was done north and south on what the management believes to be the Old Pewabic lode, and the result of this work has indicated a lode from six to eight feet wide, showing some copper throughout a length of 700 feet, the best showing being confined to the 325 feet south of the main adit.

President J. P. Channing reports that "it cannot be said that the lode developed is as yet one of commercial value, but certainly the showing is sufficiently good to warrant the continuance of development work."

### New Arcadian Copper Company.

Mine location: East of Quincy mine, Houghton county.

General Manager: Robert H. Shields.

Although the operations during 1914 were greatly curtailed by the war, the development work continued to show good results.

The work during the year was confined to the development of the New Arcadian lode and consisted of sinking the shaft to the 900 foot level, crosscutting east to expose the lode on two levels, drifting on the lode at four levels and extending a crosscut east beyond the lode at the 900 foot level.

Engineer Fesing states that the showing of the lode on the 900 foot level will compare favorably with any amygdaloid in the district. A number of good looking amygdaloids were found in the east crosscut. Stopping was done on the various levels and a stock-pile of about 2,500 tons has been accumulated. Arrangements have been made with the Franklin Mining Company for a mill test of this rock and the first shipment to the Franklin mill will be made early in May, 1915.

### New Baltic Copper Company.

Location of property: East of Franklin mine, Houghton county.

General Manager: Robert H. Shields.

No active mining operations was carried on during the year 1914



because of the unfavorable industrial conditions and in order to await the results of the development work on the adjoining New Arcadian property.

The very favorable results of the development work at the new Arcadian have a most important bearing on the New Baltic. All the north openings on the New Arcadian are in good copper ground and the drift on the 250 foot level is now less than 200 feet from the boundary between the two properties. Engineer Fesing states that the New Arcadian lode traverses the New Baltic property with a workable length of about 4,000 feet and that it could be worked to a depth of about 3,700 feet at its deepest portion. This would give the New Baltic approximately 170 acres on the lode and about 5,000,000 tons of recoverable rock.

The management intends to expose the New Arcadian lode from the surface at different points by means of pits and cross-trenches as soon as weather conditions will permit in 1915.

#### North Lake Mining Company.

Mine location: Lake Mine, Ontonagon county.

General Manager: R. M. Edwards.

Superintendent: Thomas Bennett.

Work was resumed in May and the unwatering of the shaft begun. The crosscut at the 300 foot level was continued in order to cut the extension of the lodes being developed on the South Lake property.

At 210 feet from the shaft the crosscut passed through No. 8 conglomerate, which point in the crosscut corresponds with the hanging of No. 8 conglomerate cut at a depth of 570 feet in the South Lake shaft. Since this point should be about 550 feet horizontally from the first of the South Lake lodes, the management expected to cut the first of these lodes by the crosscut at about 760 feet from the shaft. However, at 730 feet the crosscut broke through into the overburden. It then became necessary to build a concrete dam at the end of the crosscut to hold back the clay overburden and to sink an inclined winze to a greater depth, before going ahead with the crosscut. The winze was sunk 200 feet on an incline of 30 degrees and crosscutting was resumed at the 400 foot level.

In addition to the work now going on, general manager Edwards recommends that future exploration of the property should include the sinking of the shaft to at least 800 feet and the driving of a crosscut east at that depth to cut the lodes which diamond drilling has shown lie in that direction.

## Old Colony Copper Company.

Location of property: Calumet, Houghton county.

Superintendent: George S. Goodale.

All work during the year was confined to the extension of the diamond drill investigations of the Mayflower lode. Two drills were employed continuously in eight holes and a total of 12,774 feet of drilling was done during the year ending November 19th. This is slightly greater than the total footage of the preceding year. Superintendent Goodale states that "in places a high degree of mineralization was shown, some of the rock being thoroughly impregnated with fine copper."

It was necessary to extend several holes to a much greater depth to secure information regarding fault movements. This work has been done under the direction of Consulting Engineer A. L. Dickerman, and the later drill holes are proving his theory regarding these movements.

President Fay reports that although the operations for the year have covered a much wider area, the results are considered satisfactory, both in increased footage drilled and the fact that every hole has shown persistent mineralization.

## Osceola Consolidated Mining Company.

Mine locations: Osceola, Kearsarge and Tamarack, Houghton county.

General Manager: James MacNaughton.

Superintendent: Frank H. Haller.

During 1914 the balance of assets was increased by \$64,136.25, and the company paid out in dividends \$288,450. A total of 1,108,447 tons of ore was stamped, yielding 14,970,737 pounds of refined copper, an average of 13.5 pounds per ton.

Osceola Branch:

Mill tests of rock from No. 5 shaft made in June and July showed the rock to carry less than ten pounds to the ton and a number of the poorer stopes were abandoned. The extreme south workings of No. 6 shaft showed a gradual improvement all the year and are now in very good ore. The management decided to reopen No. 3 shaft in order to mine the large amount of foot wall rock near the shaft. A new rock-house was erected in July. Early in August all construction work was stopped and underground work at No. 5 shaft was discontinued. For general curtailment of September 1 see report of Calumet & Hecla Mining Co.

In order to prevent a loss from operations at this branch, on December 1 a system of full time with lower wages was put in force. The cost per pound, excluding mill construction, was 15.07 cents.

**North Kearsarge Branch:**

By the first of May production was normal, the repairing of No. 1 shaft was nearly finished and the lower workings unwatered. At this branch \$7,627.79 was expended for new construction. No. 1 shaft was about ready for operation early in August when all construction work was discontinued and in October this shaft was completely shut down.

In the latter part of December the boiler house building at No. 3 shaft was wrecked and operations were stopped. No. 1 shaft was then put in shape and plans made to resume production as soon as possible. Considerable repairing was necessary so no hoisting was done in 1914. The cost per pound at the North Kearsarge branch was 11.62 cents.

**South Kearsarge Branch:**

Only a small amount of development work was done at this branch during 1914. Operations were restricted chiefly to straight stoping and foot wall work. President Agassiz reports that the stopes of No. 2 shaft are rather lean and that the recovery of copper per ton of ore treated from now on to the end of this branch's productive life will probably be a decreasing factor.

A total of 6,303,000 pounds of copper was produced at an average of 16.23 pounds per ton. The cost per pound was 7.92 cents.

**Phoenix Consolidated Copper Company.**

Mine location: Near Phoenix, Keweenaw county.

General Manager: W. J. Uren.

Exploration by diamond drilling was continued along the strike of the Ashbed lode for about 3,300 feet, approximately to the boundary line between the Phoenix and Meadow properties. Five holes, totaling 2,785 feet, were drilled through the lode and general manager Uren states that nearly all of them gave fair to good copper values in the cores. This work furnished much valuable information as to the dip of the lode at depth and the desirable location for another shaft, which President Cole reports should be started in the spring of 1915, or as soon thereafter as a mill test of rock from No. 1 shaft shall prove the rock to be commercially valuable.

The No. 1 shaft was reopened and enlarged down to the third level which was the bottom of the old workings. This work was completed during April and since that time, sinking has continued steadily, showing fair copper values. The shaft was sunk a total of 758 feet and 2,010 feet of drifting was done. The total depth of the shaft was 878 feet at the end of the year. General Manager Uren states that the drifts on the 3rd, 4th, 5th and 6th levels east and west showed fair to good copper values.

For drainage purposes the "Armstrong" fissure vein adit level was reopened from its mouth at the bed of Eagle River for a distance of 581 feet. Additional equipment was installed at the power plant at No. 1 shaft and Leyner one-man drills were put in use. A small pumping plant was completed on the bank of Eagle River and dwellings for employees and machine and carpenter shops at Phoenix were repaired.

#### Quincy Mining Company.

Mine location: Hancock, Houghton county.

General Manager: Charles L. Lawton.

During the year 1914 the operations of the Quincy were seriously effected by the strike, air blasts and the European war. During the first six months\* the company did not operate at a profit and later in the summer the European war necessitated a reduction of the working force, as well as 12½ per cent reduction of wages and salaries of all employees and officers of the company. During the last two months of the year the price of copper improved and Quincy was able to sell copper which had accumulated and resumed payment of quarterly dividends which were discontinued during the strike.

Late in March a number of heavy air blasts occurred with extensive falls of rock. It may be interesting to engineers to read of the consequences of these air blasts and the means employed to prevent them as stated by general manager Charles L. Lawton:

"On March 25th, air blasts occurred throughout the mine and continued intermittently for a week or ten days. As a consequence, various crosscuts and drifts were crushed and closed up. No. 6 shaft timbers were seriously crushed between the 51st and 58th levels, and No. 2 shaft was crushed and closed between the 40th and 50th levels.

"About 500 feet of the crushed section of No. 2 shaft had to be entirely recovered and retimbered at an expense nearly as great as that of sinking a new shaft. In the remaining portion of the damaged shaft, about half of the timbers were replaced.

"Below the 50th level, the shaft was not damaged by the air blasts, though the crosscuts at the 57th, 64th, 65th and 66th levels were entirely closed, and the levels north were badly crushed.

"It was necessary to employ a considerable force of men for several months to renew and repair a large proportion of the timbers in the crushed section of No. 6 shaft, and to strengthen it by filling the old adjacent stopes with rock, while keeping the shaft in constant operation, in reopening crosscuts and drifts that were crushed and in reopening and retimbering No. 2 shaft. Thus the cost of production was increased very much during the months following the air blasts, especially because

of the loss of three months' product from No. 2 shaft, and consequently the impossibility of operating the mine, railroad and stamp-mills as economically at about 65 per cent of capacity.

"In earlier days, when air blasts were little understood, it was the custom to stope out the lode irrespective of the shaft. If the lode was rich in copper it was stoped out close over or under the shaft: where the shaft was in the lode, the latter was stoped right up to the shaft without leaving shaft pillars. Going through the upper portions of No. 2 and No. 6 shafts, is like going down through open stopes, with practically no pillars left to protect the shafts. It was in the lower part of these sections that the caving and crushing took place, with such serious results.

"For several years there has been a rigid adherence to the policy of leaving increasingly larger shaft pillars as the shafts are sunk, in order to sustain the litho-static pressure about the shafts. The air blasts have never caused any damage to these sections of the shafts. At the present bottom of the mine, these pillars are being left two hundred feet each side of the shaft.

"Air blasts have continued with more or less frequency since July, though they have not damaged or retarded the work to any great extent. There were but three fatal accidents during the year, involving less than one-fourth of one per cent of the working force.

"In order to meet the air blasts and prevent as far as possible the damages caused by them, as fast as the mining in each stope is finished, the bottom of the stope along the back of the level is filled with poor rock, constituting what is termed 'rib work.' Experience has taught that these rock packs are the most effective means yet employed to lessen the damage caused by air blasts.

"After a careful investigation and study of the effects of the series of air blasts that occurred in 1906, rib work was employed for the first time throughout what were then the lower workings of the mine to combat the damages caused by these disturbances. For a number of years, these rock packs proved effective, until the series of 1909. Again careful investigation and study readily showed that the rib work was along proper lines, but had not been carried far enough. Therefore, the packs were made deeper in the stopes—that is, doubled in size. For a still longer period of time these rock packs proved sufficient, until March 25th, 1914, when another series of air blasts occurred. For the third time it has been shown that the rock packs proved to be the best means of limiting such damage.

"In order, however, that the highest effectiveness possible may be secured within the limits of profitable mining at the greater depths, this rib work should be still further strengthened. It is estimated

that the voids in the rock give it a shrinkage of about 20 per cent at the present depth of the mine. In order to lessen this shrinkage and strengthen the rib work, the question of filling the voids in the rock with bank sand, stamp sand, or crushed rock, is receiving serious consideration, inasmuch as provisions must be made for better and stronger supports to the back of each level, as fast as stoping is finished. This must be done so as to avoid extended crushing, and thus guard the safety of the employees, minimize the losses and expenses caused by air blasts, and make permanent the mine's future operations with depth."

Throughout the year, the eight-hour work day has been in force in the mine and stamp-mills. This has necessitated the adjustment of the entire operations of the mine, in order to maintain the same output in the shorter number of hours. The mine was fully equipped with the light weight one-man hammer drilling machines in April. General Manager Lawton states that the upper levels of the mine contain many thousands of tons of lower grade ore in narrow lodes, which can be profitably mined with the lighter drilling machines. Development work was continued underground and all shafts were sinking throughout the year. An interesting fact is that the bottom drifts and stopes are showing an increase in copper contents. No. 9 shaft was not operated during the year for the sake of economy.

The new daily card system of time keeping has been improved, now includes the stamp-mills and is proving very satisfactory. At the beginning of each shaft the miners are provided with individual pocket carbide-retainers for mine lighting. These cans hold just enough carbide for a shift's work and waste is thus prevented. Small pocket lubricating oil cans have been provided for miners or machine runners and hold just enough oil for a shift's work of the drilling machine. Regular classes in First Aid Instruction have been held by the medical staff throughout the year and each successful graduate is given a certificate. As a result of this work a large decrease in the compound fracture accidents and in the percentage of infection in all accident cases have been very marked. A rigid physical examination by the medical staff is required of all applicants for positions with the company.

At the smelter the costs were high in the first six months of the year but by strict economy, improvement, and reduction of wages, about the same costs as in the previous year were maintained. The eight-hour work day went into effect at the smelter July 1st.

## Smith Explorations.

As a result of the favorable development work at the White Pine, further explorations to the west on the Nonesuch formation were started about November 1st. The exploratory work was done in Section 7, T. 50 N., R. 43 W. and Section 12, T. 50 N., R. 44 W., about eight miles west of the White Pine.

Mr. Fred Close is in charge of the exploration work and Mr. A. E. Seaman is acting as consulting geologist. Mr. Close states that at the end of January, 1915, some test-pitting has been done, a shaft had been sunk 70 feet, a crosscut made into the formation for 40 feet and 15 feet of drifting done.

The results obtained were very favorable and extensive diamond drilling will be done in the spring of 1915.

## South Lake Mining Company.

Mine location: Greenland Junction, Ontonagon county.

General Manager: R. M. Edwards.

Superintendent: Thomas Bennett.

Work was resumed in April and total openings of 1,952 feet were made during the year. The shaft was unwatered and sunk from 537 feet to 626 feet. At the 600 foot level a crosscut was driven 19 feet northwest and 1,379 feet southeast, at an average rate of better than 200 feet per month for the entire distance. This crosscut was made to explore that portion of the property in which four distinct copper bearing horizons, dipping to the south, were found by diamond drilling several years ago. The dip at the shaft is northerly and at 900 feet from the shaft the dip was found to be distinctly southerly. At the end of the year two of the copper bearing horizons dipping south had been cut in the crosscut; these have been called No. 4 south and No. 3 south. The section through shaft and crosscuts suggests the possibility that No. 4 south may be the same as No. 3 north, and No. 3 south the same as No. 1 north, as they lie approximately the same distance above No. 8 conglomerate. The 600 foot level crosscut will be extended and drifting will be pushed on the different lodes.

On the 300 foot level the crosscut was extended to the No. 1 lode and the No. 3 lode and both were opened east and west by drifts. General Manager Edwards states that all the lodes mentioned carry copper, No. 4 south where cut by crosscut and No. 3 north as far as opened, being particularly good looking.

A considerable stockpile has accumulated from the drifting on Nos. 1 and 3 north and arrangements for stamping will probably be made in the near future.

**St. Mary's Mineral Land Company.**

Agent: F. W. Nichols, Houghton.

No sales of mineral land were made during the year. The real property of the company at the close of the year consisted of 93,032.69 acres, besides the mineral rights to 14,112.96 additional acres.

During the year the company paid in assessments to the Winona Copper Company \$56,778, to the Mayflower Mining Company \$25,000 and to the Old Colony Copper Company \$80.

The St. Mary's company owns shares of stock in the following companies: Champion Copper Co., Hancock Consolidated Mining Co., La Salle Copper Co., Pacific Copper Co., Copper Range Consolidated Co., Winona Copper Co., Old Colony Copper Co., Mayflower Mining Co., Ojibway Mining Co., North Lake Mining Co., Franklin Mining Co., Houghton Copper Co., Naumkeag Copper Co. and the Douglas Copper Co.

**Superior Copper Company.**

Mine location: South of Isle Royale, Houghton county.

General Manager: James MacNaughton.

Superintendent: Ocha Potter.

Controlled by the Calumet & Hecla Mining Company.

The Superior increased its balance of assets in 1914 by \$23,175.75. A total of 3,217,635 pounds of refined copper was produced at 16.79 pounds per ton. The total cost per pound was 12.43 cents.

At the No. 1 shaft the 18th and 19th levels south on the West lode continued in fairly good copper-bearing ground. On the 18th level at 1,400 feet south of the shaft about 120 feet of stoping ground was opened. The 19th level north developed nothing of value. On the Superior lode at No. 1 shaft no new copper-bearing ground was opened. At No. 2 shaft both the West lode and the Superior lode were barren at the points opened.

As a Calumet & Hecla subsidiary, the Superior suffered the general curtailment of September 1st. For details see report of Calumet & Hecla Mining Co.

**Tamarack Mining Company.**

Mine location: Calumet, Houghton county.

General Manager: James MacNaughton.

Superintendent: John T. Been.

Controlled by the Calumet & Hecla Mining Co.

The operations of the Tamarack for the year 1914 resulted in a decrease in assets of \$174,944.97. A total of 1,074,808 pounds of re-



fined copper was produced at a total cost per pound of 29.08 cents. The copper was sold at 12.80 cents per pound.

No mining was done at No. 2 shaft during the year. In June all tram cars, engines, pumps, drills and haulage ropes were removed from the workings. No. 3 shaft was retimbered where it passes through the crushed ground. Early in the spring the drifts and stopes were repaired and hoisting began May 18th. At No. 5 shaft hoisting began May 11th. Being a high cost mine, the Tamarack early in August was closed down.

In March diamond drilling was started to continue the cross-section carried by the Cliff Mining Co. to the boundary of the Tamarack lands. Five holes were drilled and President Agassiz reports that in all of the holes a very little copper was found scattered throughout the formation, but not sufficient to warrant further exploration. All drilling was discontinued early in August.

The Tamarack was one of the few companies to continue construction work during the last quarter of the year. During the summer ground was broken for the foundations of the recrushing plant. The foundations were completed and all the steel work erected before the end of the year. When completed the plant will contain 32 Hardinge conical mills and 92 Wilfley tables.

This new mill is being built for the purpose of treating the old stamp sand in Torch Lake. Until the dredge is ready for operation part of the recrushing mill equipment will be installed to treat the tailings from the conglomerate mine. The cost of the recrushing plant will be provided by the \$230,000 the company will receive for the sale of its mill to the Lake Milling, Smelting & Refining Co.

#### Trimountain Mining Company.

Mine location: Trimountain, Houghton county.

General Manager: F. W. Denton.

Superintendent: Richard Bowden.

Controlled by the Copper Range Consolidated Co.

During the year 1914 Trimountain produced 227,251 tons of ore which yielded 5,048,306 pounds of refined copper, giving 18.21 pounds per ton. The total cost per pound was 12.21 cents and the price received per pound was 13.38 cents.

Operations were effected by the strike during the first third of the year and from August the mine was worked during the first half of each month only. Extraordinary expenditures amounted to \$12,674.93, covering completion of regrinding equipment and renewals at stamp-mill.

General manager Denton reports as follows: "Openings made during year showed average values. The property is in excellent condition and improved results are assured under favorable conditions."

Victoria Copper Mining Company.

Mine location: Victoria, Ontonagon county.

Superintendent: George Hooper.

In 1914 Victoria produced 1,486,242 pounds of refined copper, an increase of 57,549 pounds over the production of any previous year. However, the low price received for copper during the last half of the year, owing to the unsettled business conditions and the European war, resulted in a loss from mining operations of \$30,388.

Considerable development work was done and very good results obtained. A small diamond drill has been used in the mine to locate the lode when lost and to prove its width and value. A large amount of poor rock was sorted out and stored underground, especially in the lower levels. No operations were carried on at No. 6 shaft during the year.

Superintendent Hooper states that the copper from the lower levels is coarser and the stopes opened have given good results. He further states that the results obtained from the lower levels and the excellent ground shown in the shaft between the 25th and 26th levels certainly warrant the further opening of all lower levels in the mine.

The power plant was short of water during the latter part of the year and its deficiency of power made it necessary to reduce operations to one shift, thus curtailing production and adding to costs.

Extensive general repairs have been made at the stamp-mill. A compressed air locomotive for underground haulage was purchased during the year but is not yet in use. Considerable repairing was done to dwellings.

On February 1 all men employed in the mine and stamp-mill and hoisting engineers were put on an eight-hour shift and all other surface men on a nine-hour shift. This change raised the cost of production somewhat. On September 1 a general reduction in wages of 15 per cent was made.

With higher prices and ordinary condition of water supply, the Victoria should operate at a fair profit.

### White Pine Copper Company.

Mine location: Porcupine Mountain District, Ontonagon county.

General Manager: James MacNaughton.

Superintendent: Thomas H. Wilcox.

Controlled by the Calumet & Hecla Mining Company.

Development work was carried on without interruption throughout the year. President Agassiz reports that the openings on the first level west of the No. 2 shaft have been rather poor. The 2nd level east of No. 4 shaft is badly faulted but shows good values when in the lode. The 2nd and 3rd levels west of No. 3 shaft are in fair ground and between shafts Nos. 3 and 4 are very good. The drifts on the 4th level east of Nos. 3 and 4 shafts are good as far as opened. A total of 8,000 tons of ore was hoisted, increasing the stockpile to about 28,000 tons.

Considerable construction work was done at the shafts and stamp-mill during the year. Permanent hoists are being installed at shafts Nos. 3 and 4. A boiler house to furnish power for both hoists has been built and the boilers are being put in. No. 3 permanent shaft-house is built and foundations for No. 4 are in place. The trestle connecting the two shafts with the crushing plant is being erected.

At the stamp-mill the coarse crushing plant, conveyor, mill, boiler and power house are closed in and installation of machinery is underway. The management plans to have the mill in operation May 1, 1915.

The operations for the year 1914 show an excess of expenses over receipts of \$128,479.42 and the balance of liabilities was increased to \$134,559.74.

### Winona Copper Company.

Mine location: Winona, Houghton county.

Superintendent: R. R. Seeber.

During the first few months of the year conditions at the Winona were gradually approaching normal and by July the company had reached the maximum output in its history.

A great deal of attention was being paid to the regrinding department and President Paine reports that this department in the mill was aiding materially in the saving of the finely disseminated copper in the ore and the cost of producing copper was slowly working down month by month when the European war broke out. For detailed results of the Hardinge mill regrinding department for the year see statistical tables.

As a result of the war operations were suspended on August 6th.

In October a tributary arrangement was made with mining captain Broan and about 40 former employees and on October 15th production was resumed by the leasers from certain stopes on the 3rd, 4th and 5th levels of No. 3 shaft. The results of this arrangement proved very satisfactory to the miners and to the company. A total of 9,685 tons of ore was stamped at the Centennial-Allouez mill up to the end of the year.

The only construction work done during the year was in connection with the experimental work on the Shields Classifier and the Lovett Grinding Machine.

#### Wolverine Copper Mining Company.

Mine location: Kearsarge, Houghton county.

Superintendent: Theo. Dengler.

The mine was closed on July 23, 1913 by the strike and no work was done until November 12, 1913, when, with a force of 20 men, underground operations were resumed. Shipments of ore increased slowly and normal production was reached in April, 1914. The normal production was maintained throughout the year and the Wolverine was one of the very few mines which did not suffer by the general curtailment caused by the European war. A total of 3,435,459 pounds of refined copper was produced during the year ending July 1, 1914, at an average of 18.86 pounds per ton stamped.

Blocks of ground left in the older workings with copper contents below the average of new openings are being stoped and the ore selected on various levels tributary to shafts Nos. 3 and 4. A total of 6,020 tons, or 3.2 per cent, of waste rock was hoisted during the year. This reduction in waste is due in part to careful selection underground and also to the fact that little sinking and no crosscutting was done during the year. Little regular drifting and stoping was undertaken for several months after hoisting began and about 60 per cent of the rock hoisted was obtained in cleaning up and blasting out the lode along the foot in old stopes. "Jack hammer" machines are used in cutting out the lode along the foot and the mine has been equipped throughout with improved drilling machines. At the mill a six foot Hardinge mill has replaced the Chilean mill.

#### Wyandot Copper Company.

Mine location: Winona, Houghton county.

Superintendent: Frank L. Van Orden.

The Wyandot carried on actual mining work for only five months

during the year 1914. Owing to the general business depression resulting from the war, all mining operations and development work were suspended September 1st.

During the year the winze was sunk from the 815 foot level to the 915 foot level and drifting was begun at the latter depth, about July 1. Superintendent Van Orden states that "in sinking the winze from the 815 to the 915 foot level, well mineralized vein matter was encountered 30 feet above the 915 foot level which continued, and still shows, in the sump in the bottom of the winze." He further states as follows:

"The southwest drift was driven 65 feet in splendid vein matter, the first 25 feet of which carried excellent copper values while the remainder of the distance driven, 40 feet, while showing a decrease in values, showed fair values until the time work was suspended.

"The northeast drift was driven 63 feet and showed intermittent values. The breasts of both drifts showed values at the time work was suspended."

In order to furnish the married men employment during the fall and winter months, about 350,000 feet of mixed timber was logged and sold.

President Ashley Watson reports the following:

"The Wyandot lode, which we are now developing, and which averages 28 feet in width, lies in the Baltic lode horizon, some 2,300 feet east of the Winona lode, and there is little doubt that the latter lode (Winona) is the Isle Royale lode, as No. 8 conglomerate underlies both, and can be traced from Portage Lake to and beyond the Lake mine. Other beds of conglomerate occur in such manner as to make it difficult to correlate them. However, we do know from the general location of the Wyandot lode, that we are working in the horizon where we might expect to develop the Baltic lode, and some of the local mining men do not hesitate to say that the Wyandot lode is the Baltic lode."

The prospects of developing a commercial lode appear very promising at the present time.

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**STATISTICAL TABLES.**

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**COPPER AND IRON ORE.**

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PRODUCTION OF MICHIGAN COPPER MINES.

(In pounds refined copper.)

Compiled by R. E. Hore from mining company reports, Mineral Industry, U. S. Geological Survey Report, Reports of Commissioners of Mineral Statistics of Michigan and Horace Stevens Copper Hand Book.

	Previous to 1855.	1855.	1856.	1857.	1858
Adventure . . . . .	68,000	62,034	143,336	233,941	115,678
Aztec . . . . .	38,000	3,467	51,139	29,361	6,251
Caledonia . . . . .		54,000	5,500		
Central . . . . .		83,836	64,903	53,875	
Cliff . . . . .	6,980,000	1,874,197	2,220,934	2,360,850	2,260,433
Copper Falls . . . . .	316,000	200,000	208,010	307,305	303,852
Delaware . . . . .					
Evergreen Bluff . . . . .	2,599	14,100	25,110	46,942	6,665
Eagle River . . . . .		1,500	2,600	2,000	6,637
Franklin . . . . .				6,699	113,104
Flint Steel River . . . . .		4,000			2,106
Hilton . . . . .	4,000		705		
Huron . . . . .		6,000	24,000	70,000	48,000
Isle Royale . . . . .	116,000	186,000		465,124	356,810
Mass . . . . .				16,228	12,000
Madison . . . . .			4,000		16,000
Minnesota . . . . .	3,020,000	2,080,000	3,490,714	3,952,000	3,802,914
National . . . . .	157,477	48,302	176,483	316,158	264,804
North American . . . . .	900,000	307,822	408,252	375,958	38,919
Northwestern . . . . .	144,000	154,900	80,830	5,913	
Norwich . . . . .	334,000	216,000	220,000	116,000	39,000
Ohio Trap Rock . . . . .	2,500				38,685
Pennsylvania (North- west) . . . . .	1,110,000	198,080	3,348	58,543	166,100
Pewabic . . . . .		4,301	107,667	236,254	416,603
Phoenix . . . . .	38,000	6,000	16,000	34,000	
Quincy . . . . .			13,462	122,762	306,772
Ridge . . . . .	60,000	70,631	73,874	58,790	78,690
Rockland . . . . .	20,000	116,000	293,000	756,396	623,140
Star . . . . .		1,000			
Toltec . . . . .	100,000	60,000	118,401	83,036	
Windsor . . . . .		68,000			
<b>Total pounds copper.</b>	<b>13,419,227</b>	<b>5,820,170</b>	<b>7,752,268</b>	<b>9,708,135</b>	<b>9,023,163</b>
<b>Total value.</b>	<b>\$3,146,400</b>	<b>\$1,586,160</b>	<b>\$2,218,320</b>	<b>\$2,382,500</b>	<b>\$2,129,235</b>



## PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1859.	1860.	1861.	1862.	1863.
Adventure.....	198,431	42,749	4,676	22,089	.....
Albany & Boston (Peninsula).....	.....	.....	.....	7,982	.....
Ash Bed.....	.....	.....	.....	31,822	133,183
Amygdaloid.....	.....	.....	.....	97,591	138,124
Aztec.....	18,493	6,203	.....	.....	.....
Caledonia.....	15,000	40,400	.....	.....	7,730
Carp Lake.....	.....	6,428	.....	.....	976
Central.....	241,622	114,197	248,741	484,764	619,268
Cliff.....	1,415,007	1,343,393	1,928,011	2,004,960	2,100,354
Copper Falls.....	346,174	510,818	560,011	458,299	319,348
Douglass.....	.....	27,220	.....	.....	.....
Evergreen Bluff.....	38,811	63,817	99,187	119,257	141,446
Franklin.....	233,211	484,196	1,402,078	1,466,645	1,278,684
Grand Portage.....	.....	100,000	.....	.....	355,793
Eagle River.....	12,000	9,651	.....	5,652	.....
Garden City.....	4,000	.....	14,000	.....	36,000
Huron.....	45,387	9,000	98,000	139,305	138,206
International.....	3,903	.....	.....	.....	32,563
Isle Royale.....	416,056	338,198	917,274	896,139	721,841
Knowlton.....	.....	.....	.....	22,439	85,451
Mass.....	52,682	.....	.....	.....	.....
Minnesota.....	3,344,587	2,680,500	3,016,824	2,520,000	1,677,500
National.....	488,176	1,078,609	1,383,760	865,752	561,179
Ogima.....	.....	.....	.....	.....	53,530
North American.....	22,852	.....	.....	.....	.....
Northwestern Pennsylvania (North west).....	148,144	242,097	109,920	.....	5,920
Pewabic.....	1,029,949	1,917,426	1,849,992	1,571,281	1,691,562
Phoenix.....	56,590	40,062	68,790	63,590	144,118
Quincy.....	357,114	1,940,414	2,364,852	2,306,218	2,225,407
Rockland.....	479,190	689,000	776,358	564,000	344,000
Shelden & Columbia.....	.....	100,000	.....	.....	.....
Toltec.....	32,186	7,140	.....	.....	.....
<b>Total pounds copper.</b>	<b>8,999,565</b>	<b>11,791,518</b>	<b>14,842,474</b>	<b>13,647,785</b>	<b>12,812,183</b>
<b>Total value.....</b>	<b>\$1,950,355</b>	<b>\$2,654,960</b>	<b>\$3,487,995</b>	<b>\$3,634,255</b>	<b>\$4,415,600</b>

## STATISTICAL TABLES—COPPER.

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## PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1864.	1865.	1866.	1867.	1868.
Adventure.....	1,755	7,491	4,439		
Albany & Boston (Peninsula).....	7,000	318,160	163,906	62,493	234,536
Aetna.....	6,857	4,131	58,996	62,855	2,389
Ash Bed.....	51,228	9,369	128,090	326,660	
Amygdaloid.....	135,795	418,964	340,668	161,375	122,694
Atlantic.....			13,475	1,760	1,528,258
Aztec.....		8,700	32,000	80,000	72,000
Bay State.....		75,000	210,000	114,115	
Caledonia.....	31,977				26,243
Calumet & Hecla.....				1,351,173	5,098,375
Carp Lake.....	10,546	13,185			
Central.....	901,292	1,099,242	1,333,036	1,244,441	1,800,943
Cliff.....	1,351,334	1,498,626	1,642,928	1,121,725	1,227,746
Concord.....			9,980	52,020	171,185
Conglomerate.....	58,700	102,492			
Copper Falls.....	358,808	470,000	1,137,169	2,257,485	479,384
Douglass.....		6,809	16,209	65,877	50,109
Eagle River.....			738	8,389	
Evergreen Bluff.....		375,213			
Franklin.....	1,211,335	1,559,481	1,638,994	1,402,455	1,467,476
Grand Portage.....	489,104	483,592			159,282
Hilton.....	11,179	6,411	5,767		
Huron.....	101,745	468,011		1,367,169	1,480,080
International.....	22,069	63,502	69,823		
Ile Royale.....	582,386	689,836	617,336	762,852	295,033
Knowlton.....		196,724			
Lake.....					
Madison.....		14,881	34,000		
Mass.....	9,452	12,937	10,112	10,040	18,939
Meenard.....	4,000	15,600			5,510
Minnesota.....	1,446,000	403,000	391,500	376,500	230,900
Mohawk.....					
National.....	628,516	696,168	647,371	660,922	619,820
Ogima.....	50,000	140,990	277,310	168,480	199,360
Northwestern.....	6,650				
Norwich.....	9,730	53,330			
Pennsylvania (North- west).....	163,960	379,369	128,090	336,660	
Pewabic.....	1,429,857	1,731,394	1,346,140	1,646,458	1,043,523
Phoenix.....	284,187	405,000	410,000	310,115	260,000
Quincy.....	2,498,574	1,847,500	2,114,220	1,831,448	1,461,000
Ridge.....	16,917	170,433	142,411	189,537	172,000
Rockland.....	521,624	217,500	120,000	70,400	98,500
St. Clair.....		8,815	62,200	87,720	136,665
Shelden & Columbia.....		72,912	133,497	618,946	333,118
Star.....		1,760			
Sundry companies.....					1,000,000
Total pounds copper.....	12,402,577	14,046,528	13,240,405	16,750,070	19,795,068
Total value.....	\$5,870,300	\$5,635,515	\$4,629,375	\$4,442,841	\$4,940,404

## PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1869.	1870.	1871.	1872.	1873.
Adventure.....	1,154	2,931	6,391	17,055	7,345
Albany & Boston (Peninsula).....					66,200
Aetna.....					4,650
Allouez.....	3,775				a21,163
Amygdaloid.....	33,010	47,610			28,250
Ash Bed.....				10,570	13,348
Atlantic.....	1,646,857	372,617			863,366
Aztec.....	175,267	25,288	13,153	11,550	
Caledonia.....	103,853	87,508	3,377		
Calumet & Hecla.....	12,315,771	14,061,584	16,222,590	16,163,836	18,848,265
Centennial.....	a8,290	a426,366	a743,288	a384,242	a309,785
Central.....	1,807,801	1,327,156	1,432,662	1,244,349	1,503,117
Clark.....				17,749	
Cliff.....	725,247	444,381	142,238	118,386	751,203
Conglomerate.....				163,161	280,743
Copper Falls.....	691,400	772,990	478,883	520,861	1,086,640
Concord.....		9,815	123,628	143,792	122,168
Evergreen Bluff.....	147,662	111,420	45,048		
Flint Steel River.....		30,889	92,500	45,879	76,698
Franklin.....	1,559,940	1,178,000	700,000	372,000	366,000
Grand Portage.....	72,314				
Hilton.....		3,345			
Huron.....	1,682,863	a84,183	a265,453	a553,689	a547,883
International.....		8,680	19,482	65,100	100,845
Isle Royale.....	a150,672		a181,217	a250,164	a240,100
Knowlton.....	106,977			17,559	70,442
Lake.....					
La Salle.....					
Mass.....	3,213	3,408	18,692	1,903	8,265
Meenard.....					9,269
Minesota.....	227,500	401,500	368,000	552,000	148,171
Norwich.....	5,300				
National.....	256,947	260,660	411,086	336,770	167,870
Ogima.....	18,045		9,839		
Pewabic.....	960,409	546,000	444,600	467,000	572,400
Phoenix.....	796,630	999,000	1,219,862	728,470	521,080
Quincy.....	2,460,635	2,572,980	2,338,882	2,296,308	2,800,005
Ridge.....	253,840	245,400	350,150	257,920	231,140
Rockland.....	119,000	95,000	60,000	51,000	23,400
St. Clair.....	46,197			18,072	81,867
Shelden & Columbia.....	186,368				
Star.....				535	
Tamarack.....					
Tamarack Junior.....					
Trimountain.....					
Victoria.....					
Winona.....					
Wolverine.....					
Sundry companies.....	17,022	168,000	16,000	11,220	4,800
Total pounds copper.....	26,583,959	24,286,661	25,707,021	24,821,140	29,876,478
Total value.....	\$6,230,016	\$5,096,752	\$5,728,485	\$7,979,400	\$8,726,100

a Since this table includes mines reporting their output both for the calendar and for the fiscal years, and since some of the companies report the refined copper equivalent of mineral produced and others report refined copper, the amounts do not necessarily agree with the total of either mine or smelter output.

PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1874.	1875.	1876.	1877.	1878.
Adventure.....	4,185	30,470	40,784	64,609	54,115
Albany & Boston (Peninsula).....			6,015	11,998	1,746
Allouez.....	a1,008,134	a1,385,574	a1,561,875	a1,300,279	1,131,146
Amygdaloid.....	14,840				1,259
Ash Bed.....	172,291	152,946	85,224	14,633	
Atlantic.....	1,372,406	1,531,531	1,835,041	2,054,304	2,043,863
Artec.....	13,412	16,252	27,378	29,934	23,392
Calumet & Hecla.....	20,125,225	21,473,954	21,690,737	22,568,468	25,251,128
Centennial.....	a10,618				
Central.....	1,740,603	1,466,952	2,161,400	1,995,609	1,891,053
Clark.....	7,244	67,475	38,774	34,813	21,520
Cliff.....	1,054,901	1,162,873	900,146	161,319	414,415
Concord.....	22,518	440			
Conglomerate.....	81,271	25,220	177,701	33,417	280,345
Copper Falls.....	1,070,359	407,587	17,488	11,950	11,790
Douglass.....				3,258	
Evergreen Bluff.....					71,873
Fitts Steel River.....	48,772	33,054	30,115	26,067	38,356
Franklin.....	567,790	1,166,800	1,926,641	2,339,817	2,599,528
Grand Portage.....					34,124
Gratiot.....					
Hilton.....				3,555	6,807
Huron.....	a251,005	a63,289	a63,857	a82,161	65,100
International.....	7,535	8,782	10,653	17,703	1,488
Ile Royale.....	180,876	a96,682	28,199	31,985	31,933
Island.....			48,340	88,867	
Knowlton.....	6,215	6,582		5,975	8,629
Lake Superior.....	5,228			2,106	
Madison.....					1,676
Mass.....	11,925	3,014	81,952	100,238	412,339
Mesnard.....				6,589	
Minong.....		48,344	114,537	104,892	90,596
Minnesota.....	186,338	133,419	88,954	113,148	175,027
National.....	142,052	98,878	166,647	68,737	22,736
Ogima.....					2,800
Nonesuch.....	27,450	49,687			
Osceola.....	936,000	1,330,303	1,693,737	2,774,777	2,705,998
Pewabic.....	294,607	625,271	568,995	698,777	522,826
Phoenix.....	1,398,400	1,404,276	1,396,530	1,022,493	301,172
Quincy.....	3,046,698	2,892,617	2,949,863	2,720,558	2,991,950
Ridge.....	374,113	328,447	290,018	296,815	251,837
Rockland.....	45,260	11,440	57,600	38,700	17,377
St. Clair.....	5,400				
Saginaw.....				1,800	
Shelden & Columbia.....					1,622
Sundry companies.....	33,120	48,000	83,800	55,000	4,186
<b>Total pounds copper.</b>	<b>34,266,771</b>	<b>36,070,099</b>	<b>38,143,001</b>	<b>38,880,351</b>	<b>41,486,252</b>
<b>Total value.....</b>	<b>\$8,009,356</b>	<b>\$8,180,625</b>	<b>\$7,998,430</b>	<b>\$7,327,880</b>	<b>\$6,920,540</b>

a Since this table includes mines reporting their output both for the calendar and for the fiscal years, and since some of the companies report the refined copper equivalent of mineral produced and others report refined copper, the amounts do not necessarily agree with the total of either mine or smelter output.

## PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1879.	1880.	1881.	1882.	1883.
Adventure.....	21,785	2,951	7,500	429	.....
Albany & Boston (Peninsula).....	.....	.....	.....	.....	849,400
Allouez.....	1,431,452	1,318,471	1,204,209	1,683,557	1,751,377
Ash Bed.....	.....	.....	24,804	73,636	.....
Atlantic.....	2,339,073	2,341,145	2,528,009	2,634,675	2,682,197
Aztec.....	16,737	5,757	.....	1,329	.....
Calumet & Hecla.....	26,270,943	31,675,239	31,360,781	32,053,528	33,125,045
Central.....	1,799,493	2,026,078	1,418,465	1,353,597	1,268,556
Clark.....	340	.....	.....	.....	.....
Cliff.....	134,336	78,962	79,392	66,053	10,374
Concord.....	.....	.....	10,464	28,849	.....
Conglomerate.....	140,012	233,814	386,091	734,249	222,117
Copper Falls.....	.....	6,615	669,121	587,500	804,000
Evergreen Bluff.....	30,405	10,651	968	.....	.....
Flint S.eel River.....	43,192	28,080	4,140	.....	.....
Franklin.....	2,829,703	2,236,466	2,667,952	3,264,120	3,489,308
Grand Portage.....	35,423	77,860	26,264	757,080	735,598
Hilton.....	2,050	.....	.....	.....	.....
Huron.....	29,760	70,285	254,515	364,579	720,213
International.....	417	.....	.....	5,625	16,462
Ile Royale.....	26,880	77,469	47,308	35,447	16,874
Lake Superior.....	1,806	.....	.....	.....	.....
Madison.....	.....	.....	1,534	.....	.....
Mass.....	456,294	517,159	467,684	737,440	659,474
Minnesota.....	92,762	32,033	24,227	10,672	6,226
Minong.....	72,515	27,407	15,397	21,380	.....
National.....	17,506	.....	.....	17,060	26,006
Ogima.....	17,937	5,885	16,776	4,207	3,000
Nonesuch.....	31,973	55,584	119,061	46,450	.....
Osceola.....	3,197,387	3,381,061	4,176,976	4,179,782	4,256,409
Pewabic.....	332,519	970,509	1,876,244	1,482,666	1,171,847
Phoenix.....	543,426	436,010	409,357	537,177	512,291
Quincy.....	2,639,958	3,696,263	5,702,706	5,682,663	5,549,087
Ridge.....	215,469	223,353	235,606	102,936	60,155
Rockland.....	1,924	.....	.....	.....	.....
St. Clair.....	.....	13,195	125,493	87,126	125,225
Saginaw.....	49,464	.....	.....	.....	.....
Shelden & Columbia.....	.....	46,931	10,031	3,299	.....
Tamarack.....	.....	.....	.....	.....	7,435
Tamarack Junior.....	.....	.....	.....	.....	.....
Wolverine.....	.....	.....	.....	.....	.....
Sundry companies.....	15,527	6,166	884	25,623	1,188,110
<b>Total pounds copper.....</b>	<b>42,838,468</b>	<b>49,601,399</b>	<b>53,871,959</b>	<b>56,582,734</b>	<b>59,256,786</b>
<b>Total value.....</b>	<b>\$7,327,350</b>	<b>\$9,947,673</b>	<b>\$9,971,702</b>	<b>\$10,522,416</b>	<b>\$9,457,853</b>

PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1884.	1885.	1886.	1887	1888.
Adventure.....	4,333	8,436	985		
Albany & Boston (Peninsula).....	1,225,981		131,556		
Ahmeek.....					
Allouez.....	1,932,174	2,170,476	1,725,463	885,010	314,198
Arcadian.....					
Arnold.....					
Atlantic.....	3,163,585	3,582,256	3,503,670	3,641,865	3,974,972
Aztec.....					
Baltic.....					
Belt.....					
Calumet & Hecla.....	40,474,585	47,247,990	50,518,220	46,016,123	50,295,721
Centennial.....					
Central.....	1,446,747	2,157,408	2,512,886	1,923,279	1,817,023
Champion.....					
Cliff.....	28,255	8,332	22,342	145	
Conglomerate.....	1,198,691	41,155	44,505	8,913	
Copper Falls.....	891,168	1,150,538	1,396,679	736,477	1,160,000
Delaware.....					
Evergreen.....					
Bluff.....	955	6,736	1,006	1,077	26,888
Franklin.....	3,748,652	3,999,172	4,264,297	3,915,838	3,655,751
Grand Portage.....					
Gratiot.....					
Hancock.....					
Hilton.....		10,342	19,135	17,155	14,961
Huron.....	1,927,660	2,671,163	1,996,695	1,484,103	2,375,147
International.....	178,351	27,433	7,488		
Isle Royale.....	30,164				
Kearsarge.....					829,185
Keweenaw.....					
Knowlton.....	21,368	21,976	38,806	38,870	
Lake.....					
La Salle.....					
Mass.....	562,718	363,500	247,179	16,000	70,944
Michigan.....					
Minnesota.....	1,144	12,608			
Mohawk.....					
National.....	87,368	162,252	184,706	25,187	
Ogima.....	1,106	12,291		952	
Ojibway.....					
Osceola.....	4,247,630	1,939,169	3,560,786	3,583,723	4,134,320
Pennsylvania (North west).....					
Pewabic.....	231,543				
Phoenix.....	621,004	361,108	101,804	13,497	
Quincy.....	5,680,087	5,848,530	5,923,519	5,924,519	6,367,809
Ridge.....	74,030	73,390	158,272	84,902	50,890
St. Clair.....	139,407	79,686			
Seneca.....					
Shelden & Columbia.....	9,828				
Superior.....					
Tamarack.....		181,669	3,646,517	7,405,606	11,409,217
Tamarack Junior.....					
Trimountain.....					
Victoria.....					
Winona.....					
Wolverine.....					
Sundry companies.....	1,399,262	621,466	253,316	70,122	5,860
<b>Total pounds copper.</b>	<b>69,327,796</b>	<b>72,759,082</b>	<b>80,259,832</b>	<b>75,793,363</b>	<b>86,502,886</b>
<b>Total value.....</b>	<b>\$9,494,306</b>	<b>\$7,942,597</b>	<b>\$8,788,476</b>	<b>\$8,530,342</b>	<b>\$14,510,001</b>

## PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1889.	1890.	1891.	1892.	1893.
Adventure		15,485	56,008		
Albany & Boston (Peninsula)	736,507	1,108,660	1,599,670	973,217	
Ahmeek					
Allouez	1,782,816	1,409,828	1,241,423	546,530	
Arcadian					
Arnold					
Atlantic	3,698,837	3,619,972	3,653,671	3,703,875	4,221,933
Aztec					
Baltic					
Belt					
Calumet & Hecla	48,668,296	59,868,706	63,586,620	57,925,000	62,825,674
Centennial			435,784		
Central	1,270,592	1,413,397	1,321,417	1,562,867	1,177,500
Champion					
Cliff					
Conglomerate					
Copper Falls	720,000	660,000	1,440,000	1,400,000	1,000,000
Delaware					
Evergreen					
Bluff					
Franklin	4,346,062	5,638,112	4,319,840	3,767,000	3,504,244
Grand Portage					
Gratiot					
Hancock					
Hilton			6,400		
Huron	2,219,473	1,736,777	1,215,734	460,000	562,776
International					
Isle Royale					
Kearsarge	1,918,849	1,598,525	1,727,390	1,580,192	1,546,318
Keweenaw					
Knowlton			7,120		
Lake					
La Salle					
Mass.			30,114	17,450	22,737
Michigan					
Minnesota					
Mohawk					
National	470,301	123,897	103,888	36,385	63,433
Ogima					
Ojibway					
Osceola	4,534,127	5,294,792	6,543,358	6,894,256	6,216,975
Pennsylvania (North- west)					
Pewabic					
Phoenix					
Quincy	6,405,686	8,064,253	43,049	11,103,926	14,396,477
Ridge	31,969	17,645	10,542,519	41,462	
St. Clair					
Seneca					
Shelden & Columbia					
Superior					
Tamarack	10,605,451	10,106,741	16,161,312	16,426,683	15,085,113
Tamarack Junior				796,769	1,610,259
Trimountain					
Victoria					
Winona					
Wolverine			312,112	187,962	1,025,062
Sundry companies	25,000	18,569	61,197	116,780	251,304
Total pounds copper.	87,413,996	100,695,359	114,408,626	107,540,354	113,511,805
Total value.....	\$11,894,942	\$15,819,960	\$14,574,727	\$12,431,624	\$12,105,145

PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1894.	1895.	1896.	1897.	1898.
Adventure.....					
Albany & Boston (Peninsula).....					
Ahmeek.....					
Allouez.....					
Arcadian.....					
Arnold.....					
Atlantic.....					152,320
Aztec.....	4,437,609	4,832,497	4,832,497	5,109,663	4,397,339
Baltic.....					42,766
Belt.....					
Calumet & Hecla.....	61,842,722	77,439,907	89,280,621	83,248,054	86,426,320
Centennial.....					672,000
Central.....	584,950	370,381	469,243	614,891	291,339
Champion.....					
Cliff.....					
Conglomerate.....					
Copper Falls.....					
Delaware.....					
Evergreen.....					
Bluff.....					
Franklin.....	3,602,608	3,086,933	2,746,076	2,908,384	2,623,702
Grand Portage.....					
Gratiot.....					
Hancock.....					
Hilton.....					
Huron.....					
International.....					
Isle Royale.....					
Kearsarge.....	1,998,710	1,946,163	1,337,226	(Consolidat	ed Osceola)
Keweenaw.....					
Knowlton.....					
Lake.....					
La Salle.....					
Mass.....	41,805	18,372	53,507	65,250	
Michigan.....					
Minesota.....					
Mohawk.....					
National.....	36,390	50,128			
Ogima.....					
Ojibway.....					
Osceola.....	6,879,000	6,270,373	9,528,415	11,201,103	12,682,297
Pennsylvania (North west).....					
Pewabic.....					
Phoenix.....					
Quincy.....	15,484,014	16,304,721	16,863,477	16,924,618	16,354,061
Ridge.....					
St. Clair.....					
Seneca.....					
Shelden & Columbia.....					
Superior.....					
Tamarack.....	15,375,000	14,840,000	16,044,860	20,222,529	19,660,480
Tamarack Junior.....	2,350,000	2,605,000	2,330,000	(Consolidat	ed Osceola)
Trimountain.....					
Victoria.....					
Winona.....					
Wolverine.....	1,665,255	1,817,806	2,196,791	2,316,296	4,588,114
Sundry companies.....	176,011	94,121	64,013	91,798	75,000
Total pounds copper.....	114,474,074	129,676,402	145,744,726	142,702,586	147,965,738
Total value.....	\$10,852,122	\$13,877,109	\$15,758,935	\$16,530,843	\$17,829,871



## PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1899.	1900.	1901.	1902.
Adventure.....		23,572	29,361	606,211
Albany & Boston (Peninsula).....				
Ahmeek.....				
Allouez.....				
Arcadian.....	500,000	1,350,000	500,000	600,000
Arnold.....	783,911			
Atlantic.....	4,675,882	4,930,149	4,666,880	4,949,366
Aztec.....				
Baltic.....	621,336	1,735,060	2,641,432	6,285,819
Belt.....				
Calumet & Hecla.....	89,610,963	77,761,382	82,519,676	81,248,739
Centennial.....	730,240			
Central.....				
Champion.....				4,165,784
Cliff.....				
Conglomerate.....				
Copper Falls.....				
Delaware.....				
Evergreen.....				
Bluff.....				
Franklin.....	1,230,000	3,663,710	3,757,419	5,237,460
Grand Portage.....				
Gratiot.....				
Hancock.....				
Hilton.....				
Huron.....				
International.....				
Isle Royale.....			2,171,955	3,569,748
Kearsarge.....				
Keweenaw.....				
Knowlton.....				
Lake.....				
La Salle.....				
Mass.....	42,800	122,239	950,000	2,345,805
Michigan.....	730,240	892,500	806,400	166,898
Minnesota.....				
Mohawk.....			160,897	226,824
National.....				
Ogima.....				
Ojibway.....				
Osceola.....	11,358,049	12,566,471	13,723,487	13,416,396
Pennsylvania (North-west).....				
Pewabic.....				
Phoenix.....		88,206	93,643	100,000
Quincy.....	14,301,182	14,116,551	20,540,720	18,988,491
Ridge.....				
St. Clair.....				
Seneca.....				
Shelden & Columbia.....				
Superior.....				
Tamarack.....	18,565,602	19,182,502	18,000,852	15,961,528
Tamarack Junior.....				
Trimountain.....				5,732,160
Victoria.....				
Winona.....	783,911	856,000	108,000	101,188
Wolverine.....	4,500,373	4,789,829	4,946,126	6,473,181
Sundry companies.....	50,000			
<b>Total pounds copper.</b>	<b>148,444,480</b>	<b>142,078,171</b>	<b>155,616,848</b>	<b>170,175,598</b>
<b>Total value.....</b>	<b>\$26,098,382</b>	<b>\$23,691,928</b>	<b>\$26,038,857</b>	<b>\$20,711,592</b>

PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1903.	1904.	1905.	1906.
Adventure.....	2,182,608	1,380,480	1,606,208	1,552,628
Ahmeek.....		350,000	1,552,957	3,077,507
Allouez.....				4,486,900
Atlantic.....	5,505,598	5,321,859	4,049,731	1,439,082
Aztec.....				
Baltic.....	10,580,997	12,177,729	14,384,684	14,397,557
Calumet & Hecla.....	76,490,869	80,341,019	95,100,160	100,023,420
Centennial.....		641,294	1,446,584	2,253,015
Champion.....	10,564,147	12,212,954	15,707,426	16,954,986
Franklin.....	5,309,030	4,771,050	4,206,085	4,671,570
Ile Royale.....	3,134,601	2,442,905	2,973,761	2,937,098
Mass.....	2,576,447	2,182,931	2,007,950	2,106,739
Michigan.....	275,708	2,746,127	2,891,796	2,875,341
Mohawk.....	6,284,327	8,149,515	9,387,614	9,352,252
Osceola.....	16,059,636	20,472,429	18,938,965	18,588,451
Phoenix.....	202,823	1,162,201	273,219	
Quincy.....	18,498,288	18,343,160	18,827,557	16,194,838
Tamarack.....	15,286,093	14,961,885	15,824,068	9,832,644
Trimountain.....	9,237,051	10,211,230	10,476,462	9,507,933
Victoria.....				546,334
Winona.....	1,036,944	646,025		278,182
Wolverine.....	9,024,034	9,764,455	9,464,418	9,548,123
<b>Total pounds copper.</b>	<b>192,249,201</b>	<b>208,279,248</b>	<b>229,119,645</b>	<b>230,524,600</b>
<b>Total value.....</b>	<b>\$26,383,449</b>	<b>\$27,107,107</b>	<b>\$36,616,586</b>	<b>\$43,940,489</b>

## PRODUCTION OF MICHIGAN COPPER MINES.—Continued.

	1907.	1908.	1909.	1910.
Adventure.....	1,244,874	90,870		
Ahmeek.....	5,510,985	6,280,241	9,198,110	11,844,954
Allouez.....	2,934,116	3,047,051	4,031,532	4,655,702
Baltic.....	16,704,868	17,724,854	17,817,836	17,549,762
Calumet & Hecla.....	83,863,116	82,549,979	80,096,995	72,059,545
Centennial.....	2,373,572	2,196,377	2,583,793	1,572,566
Champion.....	16,489,436	17,786,763	18,005,071	19,224,174
Franklin.....	4,401,248	3,707,518	1,615,556	966,353
Isle Royale.....	2,667,608	3,011,664	5,719,056	7,567,339
Keweenaw.....		122,474	57,091	36,682
Lake.....				318,050
La Salle.....				
Mass.....	2,078,677	1,766,930	1,723,436	1,321,885
Michigan.....	2,665,404	3,000,206	1,979,305	
Mohawk.....	10,107,266	10,295,881	11,248,474	11,412,066
Osceola.....	14,134,753	21,250,794	25,296,657	19,346,566
Quincy.....	19,796,058	20,600,361	22,511,984	22,517,014
Superior.....		21,244	1,781,315	3,181,041
Tamarack.....	11,078,604	12,806,127	13,533,207	11,063,606
Trimountain.....	8,190,711	6,034,908	5,282,404	5,694,868
Victoria.....	1,207,237	1,290,040	1,062,218	1,164,564
Winona.....	1,285,863			
Wolverine.....	9,272,351	9,955,233	9,971,482	9,666,534
Total pounds copper.....	216,006,747	223,539,515	233,515,522	221,163,271
Total value.....	\$43,751,290	\$29,601,603	\$30,586,693	\$28,450,270

PRODUCTION OF MICHIGAN COPPER MINES.—*Concluded.*

	1911.	1912.	1913.	1914.
Ahmeek . . . . .	15,196,127	16,455,769	9,220,874	13,634,605
Allouez . . . . .	4,780,494	5,525,455	4,091,129	6,056,548
Baltic . . . . .	15,370,449	13,373,961	7,736,126	7,001,945
Calumet & Hecla . . . . .	74,130,977	67,856,429	45,016,890	53,691,562
Centennial . . . . .	1,493,834	2,567,385	1,612,262	2,287,130
Champion . . . . .	15,639,426	17,225,508	12,080,594	15,807,206
Franklin . . . . .	820,203	1,710,651	1,021,440	93,283
Gratiot . . . . .	14,275			
Hancock . . . . .	754,729			488,678
Isle Royale . . . . .	7,490,120	8,186,957	4,158,548	6,601,235
Keweenaw . . . . .	633,778			
Lake . . . . .			287,200	
La Salle . . . . .			43,906	540,731
Mass . . . . .	1,326,998	2,045,006	1,713,545	2,944,952
Michigan . . . . .	327,773	162,950		
Mohawk . . . . .	12,091,056	11,995,598	5,778,235	11,094,859
Osceola . . . . .	18,388,193	18,413,387	11,325,010	14,970,737
Quincy . . . . .	22,252,943	20,634,800	12,184,128	15,356,380
Superior . . . . .	3,236,233	3,921,974	2,992,765	3,217,635
Tamarack . . . . .	7,494,077	7,908,174	4,168,743	1,074,808
Trimountain . . . . .	6,120,147	6,980,713	4,990,938	5,048,306
Victoria . . . . .	1,303,331	1,224,911	1,428,693	1,486,242
Winona . . . . .	1,275,675	2,307,337	1,448,737	1,352,085
Wolverine . . . . .	9,630,639	9,120,485	8,350,312	3,435,459
			(1912-1913)	(1913-1914)
Total pounds copper.	219,771,477	217,617,450	139,650,075	166,184,386
Total value . . . . .	\$27,743,572	\$38,001,784	\$24,042,440	\$21,426,122

## MINERAL RESOURCES OF MICHIGAN.

PRODUCTION OF COPPER IN THE UNITED STATES IN 1913 AND 1914.<sup>1</sup>

(Smelter output, in pounds fine.)

	1913.	1914.
Alaska.....	23,423,070	24,985,847
Arizona.....	404,278,809	382,449,922
California.....	32,492,285	29,784,173
Colorado.....	9,052,104	7,316,066
Idaho.....	8,711,490	5,875,205
Maryland.....		12,248
Michigan.....	155,715,286	158,009,748
Missouri.....	576,204	53,519
Montana.....	285,719,918	236,805,845
Nevada.....	85,209,536	60,122,904
New Mexico.....	50,196,881	64,204,703
North Carolina.....	180	19,712
Oklahoma.....	11	
Oregon.....	77,812	5,599
Pennsylvania.....	245,337	422,741
Philippine Islands.....	22	
South Dakota.....	4,549	
Tennessee.....	19,489,654	18,661,112
Texas.....	39,008	34,272
Utah.....	148,057,450	160,589,660
Vermont.....	5,771	
Virginia.....	46,961	17,753
Washington.....	732,742	683,602
Wisconsin.....		10,098
Wyoming.....	362,235	17,082
Undistributed.....	46,803	55,381
Totals.....	1,224,484,098	1,150,137,192
Total value.....	\$189,795,035	\$152,968,246

<sup>1</sup>Figures from U. S. G. S. report by B. S. Butler.

SUMMARY OF RESULTS OBTAINED BY MICHIGAN COPPER MINING COMPANIES IN 1914.

	Tons of ore treated.	Cost of mining, transportation, and stamping per ton.	Pounds of concentrate obtained.	Pounds of refined copper produced.	Per cent of refined copper in concentrate.	Pounds of refined copper per ton of ore treated.	Cost per pound at mine excluding construction.	Cost per pound, construction.	Cost per pound smelting, freight, commission and eastern office.	Other costs per pound.	Cost paid per pound interest.	Total cost per pound.	Price received for copper sold.
neek.....	590,519	1.55	20,333,000	13,624,605	67.06	23.1	6.73	1.68	1.30	.....	.....	9.71	13.08
meek.....	354,457	1.583	9,408,470	6,056,548	64.37	17.09	9.26	.....	1.83	.....	0.09	11.18	12.853
etc.....	324,433	2.17	.....	7,001,945	.....	21.58	9.90	.....	1.11	0.16	.....	11.17	13.38
J. & H. (all ore)	2,592,482	1.85	.....	53,691,562	.....	20.70	.....	1.00	.....	.....	.....	11.35	14.01
J. & H. (Conglomerate)	1,439,986	2.37	.....	37,996,045	.....	26.38	.....	.....	.....	.....	.....	10.42	14.01
C. & H. (Oscoda lode)	1,152,476	1.19	.....	15,695,517	.....	13.62	.....	.....	.....	.....	.....	10.20	14.01
Centennial.....	138,126	1.838	3,311,760	2,287,130	69.06	16.56	11.10	.....	1.11	.....	0.35	12.58	12.111
Champion.....	614,824	2.11	.....	15,807,206	.....	25.71	7.92	.....	0.98	0.31	.....	9.21	13.38
Franklin.....	7,324	.....	175,944	93,253	.....	12.73	.....	.....	.....	.....	.....	.....	13.99
Hancock.....	.....	.....	.....	488,678	.....	.....	.....	.....	.....	.....	.....	.....	13.889
Ile Royale.....	474,349	1.49	9,451,115	6,601,235	69.85	13.9	10.67	0.53	1.46	0.48	0.21	13.05	13.16
Le Sable.....	41,509	.....	.....	540,721	.....	11.88	.....	.....	.....	.....	.....	.....	12.797
Mass.....	200,324	.....	4,487,435	2,944,952	65.62	14.07	.....	.....	1.304	0.526	.....	13.526	12.751
Mohawk.....	646,840	1.24	14,591,000	11,094,859	76.04	17.06	7.27	.....	0.98	0.35	.....	8.23	12.47
Oscoda.....	1,108,447	1.29	20,997,900	14,970,737	71.296	13.5	9.52	0.14	1.12	.....	0.01	10.79	13.14
Quincy.....	1,016,660	.....	22,612,460	15,356,380	.....	.....	.....	.....	.....	.....	.....	.....	13.3
Superior.....	191,698	1.75	.....	3,217,635	.....	16.79	10.41	.....	2.01	.....	0.01	12.43	12.645
Tamarack.....	157,410	4.49	1,743,145	1,074,808	61.06	18.7	24.90	3.28	1.80	.....	.....	26.08	12.80
Timountain.....	227,251	2.01	.....	5,048,308	.....	18.21	10.78	.....	1.18	0.25	.....	12.21	13.38
Victoria.....	124,552	.....	2,272,450	1,565,452	.....	.....	.....	.....	.....	.....	.....	.....	.....
Winona.....	123,359	.....	2,239,110	1,352,055	.....	10.96	.....	.....	.....	.....	.....	.....	14.2
Wolverine (1913-14).....	182,127	1.92	4,606,015	3,435,459	74.59	18.86	9.85	.....	1.45	.....	.....	11.30	14.09

## SUMMARY OF FINANCIAL STATEMENTS OF MICHIGAN COPPER MINING COMPANIES FOR 1914.

	Balance of Assets (+), Liabilities (-), December 31, 1913.	Receipts.		Assessments.	Dividends.	Balance of Assets (+), Liabilities (-), December 31, 1914.
		Sale of Copper.	Sale of Silver.			
Ahmeek.....	+ \$706,128 53	\$1,783,411 07	\$4,025 54		\$200,000 00	+ \$968,771 98
Algonah.....	+27,707 39	1,695 51				+14,597 64
Allouez.....	+249,292 42	778,418 38	13,402 65			+363,822 85
Atlantic.....	+220,657 06					+231,830 39
Baltic.....	+336,317 72	936,627 19				+490,550 85
Calumet & Hecla.....	+2,419,964 05				1,000,000 00	+3,118,204 33
Centennial.....	+27,847 78	279,001 69				+24,634 69
Champion.....	+548,643 45	2,114,468 18				+1,206,819 44
Cliff.....	+46,317 52					+36,379 30
Contact.....						+4,703 36
Copper Range Consolidated.....				\$334,564 00		+1,105,226 21
Franklin.....	-100,264 87	7,617 97				+117,165 81
Gratiot.....	-379,852 73			200 00		-400,833 59
Hancock.....		65,427 05		5,424 00		+14,923 53
Houghton.....	+15,265 23					-7,650 05
Indiana.....	+6,730 05					-29,532 51
Isle Royale.....	+175,441 57	868,410 10	17,477 98			+199,815 69
La Salle.....	+158,827 04	69,199 90	3,583 25			+110,158 74
Laurium.....	-8,020 94	375,530 16		100,000 00		+14,657 14
Mass.....	-18,858 94					+45,887 12
Mayflower.....	+14,684 88			75,064 00		+55,115 64
Mohawk.....	+521,155 92	1,383,330 34			100,000 00	+852,208 98
New Arcadian.....	+24,558 22			11,623 75		+10,431 95
New Baltic.....	+3,908 27					+869 80
North Lake.....	+49,408 33					+18,946 84
Old Colony.....	+25,151 15			79,153 00		+56,971 80
Oscoda.....	+1,549,300 06	1,967,725 27			288,450 00	+1,613,436 31
Quincy.....	+746,938 34	2,041,992 31	12,630 00		55,000 00	+897,531 77
Sanger.....	-154,454 75					-166,939 51
South Lake.....	+46,606 36					-3,790 64

<sup>1</sup>Surplus of cash and quick assets Dec. 31, 1914, \$6,902,866.46; notes outstanding dated Feb. 18, 1909, \$4,134,000. On Dec. 31, 1914, \$450,000 for these notes had been purchased.

<sup>2</sup>During the year Hancock borrowed \$164,000 from eastern bankers.

SUMMARY OF FINANCIAL STATEMENTS OF MICHIGAN COPPER MINING COMPANIES FOR 1914.—Concluded.

	Balance of Assets (+), Liabilities (-), December 31, 1913.	Receipts.		Assessments.	Dividends.	Balance of Assets (+), Liabilities (-), December 31, 1914.
		Sale of Copper.	Sale of Silver.			
St. Mary's.....	+224,903 23					+115,929 80
Superior.....	+193,697 01	406,871 78	16,247 05			+216,872 78
Tamarack.....	+1,070,938 19	157,600 75				+805,803 22
Trimountain.....	+444,757 68	675,293 75		74,234 00		+503,397 91
Victoria.....	+10,685 51	133,867 15				+40,624 36
White Pine.....	-6,080 32					3 -134,559 74
Winona.....	+74,508 16	109,797 25		172,829 00		+52,948 62
Wolverine.....	+748,034 20	484,061 05				+529,109 20
Wyandot.....	+26,887 68			1,010 00		+12,205 94

<sup>a</sup>Received from sale of 7,275 shares of preferred stock at par (\$25) per share, \$181,875.00.

<sup>b</sup>For year ending June 30, 1914.

<sup>c</sup>For year ending March 31, 1915.



## MINERAL RESOURCES OF MICHIGAN.

DETAILED RESULTS OF THE HARDINGE MILL REGRINDING DEPARTMENT  
AT THE WINONA MINE.

	Total.	Cents per ton reground.	Per cent.	Units per ton reground.
Power at 1.054 cents per K. W. Hr...	\$8,116 05	13.64	79.22	12.94 K. W. Hr.
Labor.....	384 70	.65	3.75	.....
Supplies.				
Pebbles at .8 cents per pound.....	1,237 12	2.08	12.07	2.60 lbs.
Sllex Lining at 1.436 cents per pound..	57 48	.09	.56	.07 lbs.
Steel lining at 5.242 cents per pound..	197 40	.33	1.93	.063 lbs.
Incidentals.....	252 91	.43	2.47	.....
	\$10,245 66	17.22	100.00	.....
Tons stamped.....				123,339.45
Copper by assay from Hardinge mill mineral.....				265,518.00 lbs.
Copper from Hardinge mill mineral per ton stamped.....				2.1527
Tons reground.....				59,500
Copper per ton reground.....				4.462
Regrinding cost per pound copper obtained.....				.03859
Regrinding cost per ton stamped.....				.083069



## IRON ORE SHIPMENTS FROM THE MARQUETTE RANGE.

Name of Mine.	1905 and prior years.	1906.	1907.	1908.
American (Sterling).....	112,930	419	13,764	23,222
Ames.....	6,298			
Barnum (Cliff Shaft) <sup>1</sup> .....	801,851			
Bay State.....	16,637			
Bessemer (See Lillie).....				
Bessle.....	57,451	1,646		
Beaufort (Ohio).....	354,654		78,029	61,035
Blue (See Queen Group).....				
Boston (with American).....	62,542			
Braastad { Mitchell.....	136,636			
{ Winthrop.....	831,445			
Breitung No. 1.....				
Breitung Hematite No. 2.....	17,723	83,671	59,667	55,849
Buffalo <sup>2</sup> .....	217,730			
Cambria.....	1,639,152	40,628	135,145	85,977
Champion.....	4,160,289	115,007	107,577	313
Chase.....				
Chester (See Rolling Mill).....				
Chicago.....	9,012			
Cleveland <sup>3</sup> .....	2,806,298			
Cleveland Hematite (Included under Cleveland).....				
Cleveland Cliffs Group <sup>4</sup> .....	11,562,222	1,330,944	1,030,928	438,379
Columbia (Kloman).....	94,813			
Curry.....	16,671			
Dalilba (Phoenix).....	59,114			
Detroit.....	140,841			
Dexter.....	118,512			
Dey.....	2,709			
East Champion.....	76,002			
East New York.....	327,604			
Edison.....	893			
Edwards (See Sampson).....				
Empire.....			40,565	53,537
Erie.....	8,136			
Etna.....	1,091			
Fitch.....	31,817			
Foster <sup>5</sup> .....	171,893			
Foxdale.....	31,447			
Gibson.....	16,357			
Goodrich.....	49,754			
Grand Rapids (Davis).....	110,736			
Green Bay (See Bay State).....				
Hartford.....	544,943	364,801	328,161	278,366
Hilmrod.....				
Hortense (North Champion).....	30,574			
Home (P. and L. S.) (Now Volunteer).....	26,022			
Humboldt (Washington).....	713,961			
Imperial.....	152,150	5,076	55,756	48,231
Indiana (See Bay State).....				
Iron Cliffs <sup>6</sup> .....	1,700,537			
Iron Mountain.....	393			
Jackson.....	3,802,042	5,066	61,345	
Keystone (See East Champion).....				
Lake <sup>10</sup> .....				
Lake Angeline.....	7,232,262	269,116	283,373	220,410
Lake Superior.....	13,010,436	635,671	674,066	261,955
Lillie.....	1,564,824	32,781	80,545	8,632
Loyd.....				
Lucy (McComber).....	516,159	85		1,115
Maas.....			32,378	29,036
Magnetic (Stock Pile).....		292		
Manganese (Negaunee).....	6,359			
Marquette <sup>7</sup> .....	152,847			
Mary Charlotte.....	304,926	257,088	155,633	99,104
Mesabi's Friend.....	16,043			
Michigamme <sup>8</sup> .....	880,362			

See foot notes 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 on pages 224 and 225

IRON ORE SHIPMENTS FROM THE MARQUETTE RANGE.

1909.	1910.	1911.	1912.	1913.	1914.	Total.
90,001	163,290	195,197	122,211	162,253	84,845	68,132 8,298 801,851 16,637
72,987	23,427	2,683				59,097 592,8.5
						62,542 136,636 831,445
129,673	114,202	63,497 72,688	57,085 63,995	30,994 83,280	49,590 27,705	201,166 708,453 217,730
136,815 11,199	150,422 18,746	85,954	69,904	169,153	132,834	2,645,984 4,413,131
				52,930	19,708	72,638
						9,012 2,806,298
877,433	955,374	514,305	1,032,836	922,005	672,428	19,336,854 94,813 16,671 59,114 140,841
						118,512 2,709 76,002 327,604 893
108,993	53,687	16,954	33,124	38,348		345,208 8,136 1,091 31,817
						171,893 31,447 16,357 49,754 110,736
250,680	183,471				14,466	1,950,422 14,466 30,574 26,022
115,478	83,404	86,959	53,943	37,543		713,961 638,540
						1,700,537 393
11,060	40,320	22,303	53,559	1,519	20,241	4,017,455
280,298 349,435	244,923 271,445	167,258 167,352	151,910 169,326	102,762 164,834	128,073 133,519	9,080,385 15,838,039
61,708	10,121	25,597	26,119			1,810,327
1,672	11,257	28,003	44,224	135,746	123,211	331,184
159,197	208,103	16,676 24,926	72,724 46,664	171,475	55,903	619,688 727,682 292
						6,359 152,847
240,433	197,522	340,335	250,700	262,431	57,138	2,165,310 16,043 880,362

## IRON ORE SHIPMENTS FROM THE MARQUETTE RANGE.—Continued.

Name of Mine.	1905 and prior years.	1906.	1907.	1908.
Miller.....	4,756			
Milwaukee-Davis.....	375,451			
Mitchell.....	17,780			11,539
Moore.....	68,131			
Morris.....				
National.....	150,216			
Negaunee.....	2,568,073	253,448	196,170	232,219
Negaunee Construction Works.....	12,708			
New York (York).....	1,123,071			
New York Hematite.....	37,587			
North Champion (See Hortense).....				
North Republic.....	289			
Nonpareil (St. Lawrence).....	23,395			
Northwest.....	1,687			
Norwood.....	5,753			
Ogden.....	986			
Pascoe.....	59,806			
Pendill.....	45,993			
Palmer.....	1,041	13,131		
Palmer (Cascade) (See Volunteer).....				
Pioneer.....	15,409			
Pittsburg & Lake Angelina (See Lake Angelina).....				
Platt.....	73,844			
Portland.....				
Primrose.....	6,040			
Prince of Wales <sup>1</sup> .....	32,415			
Quartz.....	491			
Queen <sup>2</sup> .....	180,866			
Queen Group <sup>3</sup> .....	4,443,378	221,096	309,917	104,098
Republic.....	5,601,121	177,220	170,554	67,999
Republic Reduction Co.....	47,174			
Richards.....	8,261			
Richmond.....	400,176	89,563	35,156	60,994
Riverside.....	16,160			
Rolling Mill.....	344,426		49,204	52,147
Saginaw.....	451,424			
Salisbury <sup>4</sup> .....	686,411			
Sam Mitchell (See Mitchell).....				
Sampson (Argyle).....	267,805			
Shadt.....	1,261			
Section 12.....	21,887			
South Buffalo <sup>5</sup> .....	245,412			
Spurr.....	165,244			
Star West (Wheat).....	204,649			
St. Lawrence (See Nonpareil).....				
Sterling (See American).....				
Taylor.....	32,970			
Teal Lake (See Cambria).....				
Titan.....	90,371			
Volunteer (See also Home).....	1,344,609	38,544	10,022	20,625
Washington.....				
Webster.....	34,905			
West Republic.....	133,077			
Wetmore.....	50,870			
Wheeling.....	433,771			
Winthrop <sup>6</sup> .....	1,335,839			
Wheat (See Star West).....				
Totals.....	75,873,089	3,935,293	3,907,955	2,214,782

<sup>1</sup>Under Iron Cliffs 1890-1895; under Cleveland-Cliffs group after 1895.<sup>2</sup>Under Queen group after 1890.<sup>3</sup>Under Cleveland-Cliffs group after 1883.<sup>4</sup>Includes Cleveland after 1883; includes Barnum, Foster, Iron Cliffs, Michigamme and Salisbury after 1895.<sup>5</sup>Under Iron Cliffs 1891-1895; under Cleveland-Cliffs group after 1895.

STATISTICAL TABLES—IRON ORE.

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IRON ORE SHIPMENTS FROM THE MARQUETTE RANGE.—*Concluded.*

1909.	1910.	1911.	1912.	1913.	1914.	Total.
		7,781	11,536	10,310		4,756
	23,428	21,387	21,141	15,970		405,078
			1,529	18,394	29,063	111,245
						68,131
						48,986
312,217	348,818	140,040	442,190	327,447	247,434	150,216
						5,088,106
						12,708
						1,123,071
						37,587
						289
						23,395
						1,687
						5,753
						986
						59,806
						45,993
						14,172
						15,409
						73,844
79,652	49,584				45,324	174,560
						6,040
						32,415
						491
						180,866
237,509	230,119	295,962	224,862	235,648	178,574	6,481,163
176,575	150,732	113,137	156,867	135,879	52,562	6,802,646
						47,174
						8,261
102,566	95,772	47,293	117,873	138,394	129,551	1,217,338
						16,160
133,139	115,193	96,584	115,784	163,287	98,010	1,167,774
						451,424
						686,411
						267,805
						1,261
						21,887
						245,412
						165,244
						204,649
						32,970
						90,371
		51,240	9,008	47,220	38,438	1,539,081
44,716	96,769	62,010	66,540	60,171	1,659	352,490
						34,905
						133,077
						50,870
						433,771
						1,335,839
3,983,436	3,840,129	2,666,121	3,415,654	3,487,993	2,340,326	105,664,778

<sup>6</sup>Under Cleveland-Cliffs group after 1895.

<sup>7</sup>Under Winthrop after 1892.

<sup>8</sup>Includes Buffalo, Prince of Wales, Queen and South Buffalo after 1890.

<sup>9</sup>Prior to 1890, see Braastad; includes Marquette after 1892.

<sup>10</sup>Included in Cleveland Cliffs Group.

## IRON ORE SHIPMENTS FROM THE GWINN DISTRICT. (GROSS TONS)

	1905 and prior years.	1906.	1907.	1908.
(Austin).....			195,950	111,229
Gwinn.....				
(Princeton) (Swanzy or Chesire).....	847,447	166,894	177,863	36,033
Stegmiller.....			6,305	52,588
(Stephenson).....				
<b>Total</b> .....	<b>847,447</b>	<b>166,894</b>	<b>380,118</b>	<b>199,850</b>

## IRON ORE SHIPMENTS FROM THE GOGEBIC RANGE, MICHIGAN.

	1905 and prior years.	1906.	1907.	1908.
Ada (Included in Ironton).....				
Anvil and North Anvil.....	543,420	79,493	39,495	35,937
Ashland.....	4,228,036	341,841	298,056	259,611
Asteroid.....				
Aurora (Norrie-Aurora Group after 1904).....	3,961,684			
Bessemer.....	20,889			
Blue Jacket.....	1,799			
Brotherton.....	1,301,127	147,281	104,224	96,776
Castile.....		2,108	6,157	
Chicago.....	68,727			
Colby.....	2,014,467	113,001	94,480	58,305
Davis (Wisconsin).....	103,961			
Eureka.....	128,719	37,525	57,904	122,324
Federal.....	36,443			
First National.....	1,997			
Geneva.....	7,108			
Imperial (See Federal).....				
Iron Chief.....	12,199			
Iron Chief No. 2.....	551			
Iron King (See Newport).....				
Ironton.....	182,233	106,158	190,968	92,932
Jack Pot.....	99,090			
Meteor (Comet).....	216,367			
Mikado.....	493,339	154,043	163,891	86,617
New Davis (See Davis).....				
Newport and Bonnie.....	3,156,054	549,745	551,496	579,390
Norrie-Aurora Group (after 1904).....	13,639,279	1,245,997	1,109,085	773,243
Pabst (Norrie-Aurora Group).....	2,366,583			
Palms.....	1,278,867	5,622		
Pike.....	27,399	17,934	24,922	6,303
Puritan (Ruby).....	109,572			
Royal.....				
Section 13.....				
Sparta.....	4,862			
Sunday Lake.....	913,355	86,879	101,899	111,130
Tilden.....	4,340,752	169,897	312,496	111,184
Vaughn (See Aurora) (Norrie-Au- rora Group after 1904).....				
Wakefield.....				
Wisconsin (See Davis).....				
Yale (West Colby).....	192,174	56,657	38,010	14,874
<b>Total</b> .....	<b>39,451,053</b>	<b>3,113,981</b>	<b>3,093,083</b>	<b>2,348,626</b>

STATISTICAL TABLES—IRON ORE.

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IRON ORE SHIPMENTS FROM THE GWINN DISTRICT. (GROSS TONS)

1909.	1910.	1911.	1912.	1913.	1914.	Total.
125,858	188,588	110,839	102,530	107,365	30,493	972,852
		230			20,159	20,389
42,934	89,441	54,442	143,519	53,479	13,607	1,025,659
39,869	48,842	45,122	50,963	45,431	40,972	271,199
64,075	225,726	135,474	214,386	96,298	93,796	888,648
272,736	552,597	346,107	511,398	302,573	199,027	3,778,747

IRON ORE SHIPMENTS FROM THE GOGEBIC RANGE, MICHIGAN.

1909.	1910	1911.	1912.	1913.	1914.	Total.
22,927	7,235	310	55,610	238	5,771	790,436
259,612	231,506	151,478	211,927	2,635	123,702	6,108,404
		20,569	70,239	42,419	135,120	268,347
						3,961,684
						20,889
						1,790
103,090	102,626	65,015	149,930	70,138	47,662	2,196,869
26,982	20,197	23,597	136,703	57,595	36,569	309,908
						68,727
170,095	194,754	41,673	245,195	305,744	291,947	3,529,661
115,662	41,611	98,609	65,723	14,562	23,430	103,961
						706,069
						36,443
						1,997
				31,303		38,411
						12,199
						551
277,594	109,025	63,359	173,135	166,123	51,138	1,412,665
						99,090
99,195	52,715			33,111	2,094	216,367
						-1,085,005
1,008,354	1,182,324	555,853	966,435	1,139,666	702,861	10,392,178
977,054	1,333,006	883,910	1,500,758	1,503,451	985,199	23,950,982
			39,152	88,644	173,792	2,366,583
22,174	3,324					1,586,077
						102,056
	50,019		90,683	64,463	58,410	373,147
				10,659	11,686	22,345
				3,844		3,844
93,712	115,486	56,096	155,485	110,374	54,327	4,862
						1,798,743
154,506	99,937	138,387	158,191	97,686	114,777	5,697,613
				15,261	313,050	328,311
71,458	108,253	154,944	76,772	89,482	19,074	821,698
3,402,415	3,652,918	2,253,800	4,094,938	3,847,398	3,150,809	68,407,921



## IRON ORE SHIPMENTS FROM THE MENOMINEE DISTRICT, MICHIGAN.

	1905 and prior years.	1906.	1907.	1908.
Antoine.....	1,056,941	195,855	100,996	
Aragon.....	4,490,305	431,000	441,636	226,354
Breen.....	34,055	21,004	20,366	
Briar Hill.....	14,981			
Chapin.....	13,404,416	943,425	855,308	391,620
Clifford & Traders.....				
Cornell.....	49,302			
Cuff.....	58,419			
Cundy.....	807,967			1,410
Curry.....	416,928			
Cyclops.....	286,093			
Eleanor (Appleton).....	13,921	3,121	1,677	
Emmett.....	66,655			
Forest.....	11,988			
Half and Half.....	7,524			
Hamilton.....	96,072			
Hersel.....	955			
Indiana.....	17,871			
Keel Ridge.....	93,101			
Loretto.....	844,884	140,390	99,779	13,354
Ludington.....	1,001,518			
Millie (Hewitt).....	298,550	36,815	18,691	3,322
Munro.....	133,254	47,454	46,834	27,773
Norway.....	1,291,352			
Penn Iron Mining Co.....	3,355,423	496,582	381,128	176,211
Perry.....	3,138			
Pewabic.....	5,135,259	493,891	457,796	365,341
Quinnsec.....	499,756			
Saginaw (Perkins).....	396,225	21,017	26,080	38,669
Stephenson.....	39,350			
Sturgeon River.....	19,404			
Verona.....	130,975			
Vivian.....	224,286	122,577	48,493	10,056
Vulcan (with Penn Mines).....	1,668,654			
Walpole.....	19,089			
<b>Total.....</b>	<b>36,018,571</b>	<b>2,953,131</b>	<b>2,498,784</b>	<b>1,254,110</b>
<b>METROPOLITAN TROUGH.</b>				
Groveland.....	26,123		13,913	9,123
Metropolitan.....	107,027			
Northwestern.....	35,810			
<b>Total.....</b>	<b>168,960</b>		<b>13,913</b>	<b>9,123</b>
<b>CALUMET TROUGH.</b>				
Calumet.....	38,713	15,773	51,646	15,222

IRON ORE SHIPMENTS FROM THE MENOMINEE DISTRICT, MICHIGAN.

1909.	1910.	1911.	1912.	1913.	1914.	Total.
						1,353,792
246,984	241,046	201,269	244,812	230,958	188,765	6,943,129
						75,425
587,647	465,543	357,598	327,999	369,822	341,493	14,981
						18,044,871
103,626	91,081	90,940	74,144	95,311	66,329	521,431
						49,302
5,512						58,419
						844,889
						416,928
						286,093
						18,719
						66,655
						11,988
						7,524
						96,072
						955
						17,871
						93,101
96,613	116,048	18,579	135,177	158,257	45,449	1,668,530
						1,001,518
10,887		18,556			361	387,182
23,241	20,022	9,303	20,100	18,509		346,490
						1,291,352
428,004	344,760	377,026	426,743	416,410	214,827	6,617,114
						3,138
465,453	380,376	352,598	279,771	364,176	299,228	8,593,849
3,147	744					503,647
19,994						501,985
						39,350
						19,404
						130,975
	14,827	5,971	28,800	27,177		482,187
						1,668,654
						19,089
1,991,108	1,674,447	1,431,840	1,537,546	1,680,620	1,156,452	52,196,609
24,933	26,462	33,758	12,468	9,251		156,031
						107,027
						35,810
24,933	26,462	33,758	12,468	9,251		298,868
			35,587	18,976		175,917

## IRON ORE SHIPMENTS FROM THE CRYSTAL FALLS DISTRICT, MICHIGAN.

	1905 and prior years.	1906.	1907.	1908.
Alpha.....	1,370			
Armenia.....	247,061	27,882	36,665	
Bristol (Claire).....	954,535	298,031	345,676	190,300
Carpenter.....				
Columbia.....	942,703			
Crystal Falls.....	1,507,940	111,871	114,158	296
Delphic.....	33,770			
Dunn.....	1,086,178	91,476	141,992	8,829
Fairbanks.....	8,500			
Genesee (Ethel).....	285,899	80,971	38,984	
Gibson.....	16,357			4,548
Great Western.....	1,089,526	311,218	234,492	124,246
Hemlock.....	1,169,885	106,437	117,181	83,834
Hilltop.....	12,409	7,820		
Hollister.....	4,098		6,371	10,671
Hope.....	28,530			
Judson.....				
Kimball.....			16,224	
Lamont (Monitor).....	423,271	89,980	42,090	
Lee Peck.....	2,844			
Lincoln.....	233,366	5,890	714	
Magnate.....	6,844			
Mansfield.....	756,120		183,532	44,633
Mastodon.....	425,708			
McDonald.....				
Michigan.....	113,219	146	39,819	603
Monongahela.....	9,310			
Paint River (Fairbanks).....	267,163	28,321	75,805	
Ravenna.....				
Richards.....				
Sheldon & Shafer (Union) (See Col- umbia).....				
South Mastodon.....	8,203			
Tobin.....	399,779	235,867	237,781	161,642
Youngstown.....	151,425			
<b>Total.....</b>	<b>10,186,013</b>	<b>1,395,910</b>	<b>1,631,484</b>	<b>629,602</b>

IRON ORE SHIPMENTS FROM THE CRYSTAL FALLS DISTRICT, MICHIGAN.

1909.	1910.	1911.	1912.	1913.	1914.	Total.
						1,370
	65,473	51,862	150,808	83,202	50,501	713,454
396,825	270,742	322,729	438,900	379,169	172,006	3,768,913
					51,147	51,147
						942,703
986						1,735,251
						33,770
193,396	136,144	232,092	242,304	61,080	52,883	2,246,374
						8,500
65,585	66,185	25,342	4,248			507,214
						158,881
36,246	45,202	56,528				2,091,081
112,747	80,709	84,338	3,342	50,464		2,098,760
112,481	115,407	107,753	126,132	113,201	46,449	28,452
					8,223	143,119
25,842	49,434	5,022		25,251	16,430	28,530
						6,619
						6,619
	3,183					16,224
						558,524
						2,844
1,657						241,627
						6,844
118,713	114,357	54,646		190,503		1,462,504
						425,708
1,114	6,022	5,240	1,384	16,499		30,259
	17,922			27,917	9,471	209,107
						9,310
		127	18,303	70,766	49,308	371,289
					7,069	138,504
						7,069
						8,203
359,668	235,812	308,456	319,318	154,896	65,351	2,478,570
						151,425
1,425,261	1,206,592	1,254,135	1,304,739	1,172,948	535,457	20,742,140

## MINERAL RESOURCES OF MICHIGAN.

## IRON ORE SHIPMENTS FROM THE IRON RIVER DISTRICT, MICHIGAN.

	1905 and prior years.	1906.	1907.	1908.
Baker .....				
Baltic .....	489,586	186,495	189,119	129,037
Bengal .....				
Berkshire .....				3,440
Beta .....	4,211			
Caspian .....	16,578	80,875	138,867	102,628
Cortland .....				
Chatham-Riverton .....			14,883	45,826
Davidson No. 1 .....				
Davidson No. 2 .....				
Chicago .....				
Fogarty .....			7,949	32,560
Forbes .....				
Hiawatha .....	210,663	20		138,190
Iron River .....	904,587			
James (Osana) .....			2,360	59,760
*Dober-Isabella .....	65,192			
Nanaimo .....	227,890	91,792	53,778	305
Riverton (Dober and Isabella) .....	670,763	161,704	90,358	47,073
Rogers .....				
Selden .....	2,092			
Sheridan .....	116,299			
Tully .....				
Virgil .....				
Wauseca .....				
Wickwire .....				
Youngs .....	10,926	47,583	92,632	70,094
Zimmerman .....				1,832
<b>Total .....</b>	<b>2,718,787</b>	<b>568,469</b>	<b>589,946</b>	<b>630,745</b>

\*Riverton.

IRON ORE SHIPMENTS FROM THE IRON RIVER DISTRICT, MICHIGAN.

1909.	1910.	1911.	1912.	1913.	1914.	Total.
45,003	39,417	3,290		24,286	113,733	225,729
174,426	171,930	66,502	100,736	130,631	29,206	1,667,668
				23,259	5,539	28,798
34,295	97,999	22,272	33,422		23,826	215,254
						4,211
189,023	171,334	165,660	306,914	295,841	279,379	1,747,099
			17,499	26,823	15,316	59,638
68,730	51,988	58,054	135,298	107,604	19,455	501,838
		215	27,614	115,499	70,881	214,209
		45,219	98,760	79,948	51,686	275,613
		108,947	149,619	137,002	114,849	510,417
77,356	51,071	67,616	84,074	124,568	15,329	460,523
				69,435	77,960	147,395
136,739	128,884	116,633	220,106	160,511	91,370	1,203,116
90,851	78,388	50,439	75,702	176,634	73,832	904,587
						607,966
						65,192
						373,765
171,200	84,269	200,142	171,493	160,818	176,274	1,934,094
					27,081	27,081
						2,092
						116,299
	2,726	8,323		16,650	63,411	91,110
			3,750	48,395	5,972	58,117
		749		12,377		13,126
		1,919	40,417	40,322	25,584	108,242
154,150	98,399	89,450	83,528	43,649		690,411
10,303	25,555	110,084	187,584	149,309	172,720	657,387
1,152,076	1,001,960	1,115,514	1,736,516	1,943,560	1,453,403	12,910,976

## MINERAL RESOURCES OF MICHIGAN.

## SUMMARY OF IRON ORE SHIPMENTS FROM MICHIGAN RANGES. (GROSS TONS.)

	1901 and prior years.	1902.	1903.	1904.	1905.
Marquette.....	62,368,847	3,749,977	2,956,022	2,767,242	4,086,943
Gwinn.....	440,636	118,048	84,223	76,461	129,079
Menominee.....	26,033,394	3,001,189	2,528,819	1,712,800	2,741,169
Crystal Falls.....	6,265,440	1,003,785	824,461	917,969	1,174,366
Iron River.....	1,464,196	355,110	276,785	284,273	337,973
Gogebic.....	29,072,290	3,018,255	2,465,263	2,042,398	3,215,352
Metropolitan.....	136,826	8,923	18,574	4,737	
Calumet.....	38,913				
<b>Total.....</b>	<b>125,820,442</b>	<b>11,255,287</b>	<b>9,154,147</b>	<b>7,805,880</b>	<b>11,684,432</b>
	1906.	1907.	1908.	1909.	1910.
Marquette.....	3,935,293	3,907,955	2,214,782	3,983,436	3,840,129
Gwinn.....	166,894	380,118	199,850	272,736	552,597
Menominee.....	2,953,131	2,498,784	1,254,110	1,991,108	1,674,447
Crystal Falls.....	1,395,910	1,631,484	629,602	1,425,261	1,206,592
Iron River.....	568,469	589,946	630,745	1,152,076	1,001,960
Gogebic.....	3,113,981	3,093,083	2,348,626	3,402,415	3,652,918
Metropolitan.....		13,913	9,123	24,933	26,462
Calumet.....	15,773	51,646	15,222		
<b>Total.....</b>	<b>12,149,451</b>	<b>12,166,929</b>	<b>7,302,060</b>	<b>12,251,965</b>	<b>11,955,105</b>
	1911.	1912.	1913.	1914.	Total.
Marquette.....	2,614,881	3,406,646	3,487,993	2,340,326	105,660,022
Gwinn.....	346,104	510,398	302,573	199,027	3,778,747
Menominee.....	1,431,840	1,538,746	1,680,620	1,156,452	52,196,609
Crystal Falls.....	1,254,135	1,304,739	1,172,948	535,457	20,742,149
Iron River.....	1,115,514	1,736,966	1,943,560	1,453,403	12,910,976
Gogebic.....	2,102,322	3,883,011	3,847,398	3,150,609	68,407,921
Metropolitan.....	33,758	12,468	9,251		298,868
Calumet.....		35,387	18,976		175,917
<b>Totals.....</b>	<b>8,898,554</b>	<b>12,428,361</b>	<b>12,463,319</b>	<b>8,835,274</b>	<b>264,171,209</b>

STATISTICAL TABLES—IRON ORE.

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SHIPMENTS OF IRON ORE FROM MICHIGAN RANGES BY COUNTIES.  
(GROSS TONS.)

County.	1901 and prior years.	1902.	1903.	1904.	1905.
Gogebic.....	29,072,290	3,018,255	2,465,263	2,042,398	3,215,352
Iron.....	7,729,636	1,358,895	1,101,246	1,202,242	1,512,339
Dickinson.....	26,209,033	3,010,112	2,547,393	1,717,537	2,741,169
Marquette.....	62,258,919	3,808,244	2,905,597	2,817,195	4,175,605
Baraga.....	550,564	59,781	134,648	26,508	39,967
<b>Total.....</b>	<b>125,820,442</b>	<b>11,255,287</b>	<b>9,154,147</b>	<b>7,805,880</b>	<b>11,684,432</b>

County.	1906.	1907.	1908.	1909.	1910.
Gogebic.....	3,113,981	3,093,083	2,348,626	3,402,415	3,652,918
Iron.....	1,964,379	2,221,430	1,260,347	2,577,337	2,208,552
Dickinson.....	2,968,904	2,564,343	1,278,455	2,016,041	1,700,909
Marquette.....	4,097,111	4,154,288	2,305,366	3,888,055	4,236,311
Baraga.....	5,076	133,785	109,266	368,117	156,415
<b>Total.....</b>	<b>12,149,451</b>	<b>12,166,929</b>	<b>7,302,060</b>	<b>12,251,965</b>	<b>11,955,105</b>

County.	1911.	1912.	1913.	1914.	Total.
Gogebic.....	2,102,322	3,883,011	3,836,739	3,150,609	68,407,921
Iron.....	2,369,649	3,041,705	3,116,508	1,988,860	33,653,125
Dickinson.....	1,465,598	1,585,601	1,708,847	1,156,452	52,671,394
Marquette.....	2,871,116	3,864,101	3,753,023	2,494,029	107,590,647
Baraga.....	89,642	53,943	37,543	45,324	1,848,122
<b>Totals.....</b>	<b>8,898,327</b>	<b>12,428,361</b>	<b>12,452,660</b>	<b>8,835,274</b>	<b>264,171,209</b>



## MINERAL RESOURCES OF MICHIGAN.

## LIST OF THE ACTIVE IRON MINES OF MICHIGAN.

Name of mine.	Location.				First ship- ment.	No. of men employed.	Depth, 1914.
	County.	Section.	Twp.	Rge.			
<b>CRYSTAL FALLS DISTRICT:</b>							
Bristol.....	Iron.....	19	43	32	1892	135	1,060
Carpenter.....	Iron.....	31	43	32	1914	187	1,222
Dunn-Richards.....	Iron.....	1	42	33	1887	76	1,623
Genesee (with Tobin).....	Iron.....	29,30,31	43	32	1902	.....	.....
Great Western.....	Iron.....	21	43	32	1882	48	1,257
Hemlock.....	Iron.....	4	44	33	1891	105	1,015
Judson.....	Iron.....	13	42	33	1914	95	300
Michigan (with Hemlock).....	Iron.....	9	44	33	1893	.....	1,015
Ravenna.....	Iron.....	19	43	32	1911	135	350
Tobin.....	Iron.....	30	43	32	1901	8	1,235
<b>IRON RIVER DISTRICT:</b>							
Baker-Tully.....	Iron.....	31	43	34	1909	214	548
Baltic.....	Iron.....	7	42	34	1901	73	553
Bengal.....	Iron.....	36	43	35	1913	19	281
Berkshire.....	Iron.....	6	42	34	1908	14	365
Caspian.....	Iron.....	1	42	35	1903	303	292
Chatham-Riverton.....	Iron.....	35	43	35	1907	26	700
Chicagon.....	Iron.....	26	43	34	1911	111	712
Cortland.....	Iron.....	34	43	35	1912	8	405
Davidson No. 1.....	Iron.....	23	43	35	1912	101	450
Davidson No. 2.....	Iron.....	14	43	35	1912	78	240
Fogarty (see Baltic).....	Iron.....	1	42	35	1907	.....	365
Forbes.....	Iron.....	14	43	35	1913	122	275
Hiawatha.....	Iron.....	35	43	35	1893	96	895
Osana (James).....	Iron.....	23	43	35	1907	92	428
Dober Isabella (Riverton).....	Iron.....	1,35,36	42,43	35	1898	195	900
Rogers.....	Iron.....	29	43	34	1914	96	330
Tully (see Baker).....	Iron.....	36	43	35	1910	.....	548
Virgil.....	Iron.....	24	43	35	1912	.....	273
Wauseca.....	Iron.....	23	43	35	1910	8	398
Wickwire.....	Iron.....	35	43	35	1911	42	313
Youngs.....	Iron.....	12	42	35	1905	2	515
Zimmerman.....	Iron.....	7	42	34	1908	140	350
<b>GOGBIC RANGE:</b>							
Anvil and Keweenaw.....	Gogebic.....	14	47	46	1887	40	1,663
Asteroid.....	Gogebic.....	13	47	46	1906	157	1,135
Ashland.....	Gogebic.....	22	47	47	1885	188	1,900
Brotherton.....	Gogebic.....	9	47	45	1886	133	1,157
Castile.....	Gogebic.....	10	47	45	1906	157	1,470
Colby.....	Gogebic.....	16	47	46	1884	277	1,289
Davis, Geneva, Royal, Puritan.....	Gogebic.....	17, 18 19, 20	46	47	1886	187	1,754
Eureka.....	Gogebic.....	13	47	46	1890	140	1,500
Ironton (see Colby).....	Gogebic.....	17	47	46	1886	.....	1,350
Keweenaw (see Anvil).....	Gogebic.....	11	47	46	1914	.....	1,663
Mikado.....	Gogebic.....	18	47	45	1895	29	1,131
Newport and Bonnie.....	Gogebic.....	24	47	47	1886	899	2,154
Norrie-Aurora Group.....	Gogebic.....	22, 23	47	47	1884	1,323	1,676
Palms (see Anvil).....	Gogebic.....	14	47	46	1912	310	1,663
Puritan (see Davis).....	Gogebic.....	17	47	46	1886	.....	.....
Sunday Lake.....	Gogebic.....	10	47	45	1885	216	1,291
Tilden.....	Gogebic.....	15	47	46	1891	276	1,326
Wakefield.....	Gogebic.....	16, 17	47	45	1913	283	256
Yale.....	Gogebic.....	16	47	46	1901	93	861

¹Depth of North Norrie.

1914, WITH LOCATION, OWNERSHIP, ETC.

Number or name of level.	Operators.	Address of Home Office.
11th	Bristol Mining Co. ....	Wade Building, Cleveland, Ohio.
1st	Hollister Mining Co. ....	1300 Leader-News Bldg., Cleveland, Ohio.
13th	Corrigan, McKinney Co. ....	Wickliffe, Ohio.
...	Corrigan, McKinney Co. ....	Wickliffe, Ohio.
16th	Corrigan, McKinney Co. ....	Wickliffe, Ohio.
14th	Hemlock River Mining Co. ....	Cleveland, Ohio, Western Reserve Bldg.
1st	Judson Mining Co. ....	First National Bank Bldg., Chicago, Illinois.
14th	Hemlock River Mining Co. ....	Cleveland Ohio, Western Reserve Bldg.
2d	Hollister Mining Co. ....	1300 Leader News Bldg, Cleveland, Ohio.
12th	Corrigan, McKinney Co. ....	Wickliffe, Ohio.
4th	Corrigan, McKinney Co. ....	Wickliffe, Ohio.
7th	Verona Mining Co. ....	Cleveland, Ohio, Western Reserve Bldg.
2d	Verona Mining Co. ....	Cleveland, Ohio, Western Reserve Bldg.
4th	Brule Mining Co. ....	76 Wade Building, Cleveland, Ohio.
3d	Verona Mining Co. ....	Cleveland, Ohio, Western Reserve Bldg.
7th	Brule Mining Co. ....	76 Wade Bldg., Cleveland, Ohio.
6th	Munro Mining Co. ....	55 Erie Co. Bank Bldg., Buffalo, N. Y.
4th	Wickwire Mining Co. ....	Buffalo, N. Y.
1st	Davidson Ore Mining Co. ....	403 White Bldg., Buffalo, N. Y.
2d	Davidson Ore Mining Co. ....	403 White Bldg., Buffalo, N. Y.
4th	Verona Mining Co. ....	Western Reserve Bldg., Cleveland, Ohio.
2d	Jones & Laughlin Ore Co. ....	3d Ave. & Try St., Pittsburg, Pa.
9th	Munro Mining Co. ....	55 Erie Co. Bank Bldg., Buffalo, N. Y.
4th	Mineral Mining Co. ....	910 Wells Bldg., Milwaukee, Wis.
9th	Oliver Iron Mining Co. ....	Wolvin Bldg., Duluth, Minn.
1st	Munro Iron Mining Co. ....	55 Erie Co. Bank Bldg., Buffalo, N. Y.
.....	Corrigan, McKinney Co. ....	Wickliffe, Ohio.
2d	Wickwire Mining Co. ....	Buffalo, N. Y.
4th	Mineral Mining Co. ....	910 Wells Bldg., Milwaukee, Wis.
4th	Huron Iron Co. ....	Iron River, Mich.
5th	Wickwire Mining Co. ....	Buffalo, N. Y.
4th	Spring Valley Iron Co. ....	Wellston, Ohio, Jackson Co.
11th	Newport Mining Co. ....	First National Bank Bldg., Milwaukee, Wis.
12th	Castile Mining Co. ....	76 Wade Bldg., Cleveland, Ohio.
25th	Hayes Mining Co. ....	808 1st National Bank Bldg., San Jose, Cal.
21st	Brotherton Iron Mining Co. ....	Western Reserve Bldg., Cleveland, Ohio.
14th	Castile Mining Co. ....	76 Wade Bldg., Cleveland, Ohio.
14th	Corrigan, McKinney Co. ....	Wickliffe, Ohio.
18th	Oliver Iron Mining Co. ....	Wolvin, Bldg., Duluth, Minn.
15th	Castile Mining Co. ....	76 Wade Bldg., Cleveland, Ohio.
.....	Corrigan, McKinney Co. ....	Wickliffe, Ohio.
11th	Newport Mining Co. ....	First National Bank Bldg., Milwaukee, Wis.
16th	Verona Mining Co. ....	Western Reserve Bldg., Cleveland, Ohio.
19th	Newport Mining Co. ....	First National Bank Bldg., Milwaukee, Wis.
23d	Oliver Iron Mining Co. ....	Wolvin Bldg., Duluth, Minn.
11th	Dunn Iron Mining Co. ....	First National Bank Bldg., Milwaukee, Wis.
.....	Oliver Iron Mining Co. ....	Wolvin Bldg., Duluth, Minn.
22d	Sunday Lake Iron Co. ....	Western Reserve Bldg., Cleveland, Ohio.
21st	Oliver Iron Mining Co. ....	Wolvin Bldg., Duluth, Minn.
1st	Wakefield Iron Co. ....	1300 Leader-News Bldg., Cleveland, Ohio.
10th	Lake Superior Iron & Chemical Co.	Penobscot Bldg., Detroit, Mich., F. W. Blair, Receiver.

## LIST OF THE ACTIVE IRON MINES OF MICHIGAN.

Name of mine.	Location.				First ship- ment.	No. of men employed.	Depth, 1914. Feet.
	County.	Section.	Twp.	Rge.			
<b>MARQUETTE RANGE:</b>							
American and Boston	Marquette	32	48	28	1880	277	1,460
Breitung Hematite No. 1	Marquette	8	47	26	1903	172	585
Breitung Hematite No. 2	Marquette	8	47	26	.....	51	435
Cambria	Marquette	35	48	27	1875	125	1,300
Champion	Marquette	31, 32	48	29	1867	.....	1,984
Chase	Marquette	3	47	28	1913	79	351
Cliff Shaft	Marquette	9, 10	47	27	1887	285	987
Empire	Marquette	19	47	26	1907	2	200
Gwinn	Marquette	28	45	25	1914	133	1,009
Hartford (Cambria No. 2)	Marquette	36	48	27	1889	.....	1,300
Himrod	Marquette	7	47	26	1914	45	.....
Imperial	Baraga	25	48	31	1890	1	185
Jackson	Marquette	1	47	27	1846	29	208
Lake and Moro	Marquette	10	47	27	1892	246	591
Lake Superior (Hard Ore)	Marquette	9, 10	47	27	1858	211	1,080
Lake Superior (Soft Ore)	Marquette	10	47	27	1858	81	820
Lake Angeline	Marquette	15	47	27	1864	194	615
Lloyd (see Morris)	Marquette	6	47	27	1911	.....	808
Lucy (with Jackson)	Marquette	6, 7	47	26	1878	.....	281
Maas	Marquette	31	48	26	1907	212	1,100
Maitland (Volunteer)	Marquette	30	47	26	.....	.....	.....
Mary Charlotte	Marquette	8	47	26	1903	129	435
Morris and Lloyd	Marquette	1	47	28	1912	243	798
Moro (with Lake)	Marquette	10	47	27	1881	.....	812
Negaunee	Marquette	5, 6	47	26	1887	302	986
Ohio	Baraga	22	48	31	1882	1	250
Portland	Baraga	26	48	31	1896	55	50
Queen Group	Marquette	5	47	26	1888	252	1,010
Republic	Marquette	7	46	29	1872	264	2,050
Richmond	Marquette	28	47	26	1896	43	.....
Rolling Mill	Marquette	7	47	26	1872	215	786
Salisbury	Marquette	15	47	27	1872	117	709
Volunteer	Marquette	30	47	26	1871	25	505
Washington (Barron)	Marquette	11	47	29	1865	45	875
<b>SWANEEY DISTRICT:</b>							
Austin	Marquette	20	45	25	1907	1	364
Princeton	Marquette	18, 20	45	25	1872	10	782
Stegmiller	Marquette	17	45	25	1909	63	300
Stephenson	Marquette	20	45	25	1907	246	562
<b>MENOMINEE RANGE:</b>							
Aragon	Dickinson	8, 9	39	29	1889	279	1,155
Chapin	Dickinson	25, 30	40	31, 30	1880	553	1,501
Cyclops & Norway (Penn Grp)	Dickinson	5	39	29	1878	.....	355
East Vulcan (Penn Group)	Dickinson	10, 11	39	29	1877	.....	1,400
Loretto	Dickinson	7	39	28	1893	168	800
Millie (Hewitt)	Dickinson	31	40	34	1881	10	600
Munro	Dickinson	6	39	29	1903	1	170
Pewabic	Dickinson	32	40	30	1890	326	941
West Vulcan, Curry & Brier Hill	Dickinson	9, 10	39	29	1879	632	1,770
Clifford and Traders	Dickinson	20	40	30	.....	61	143

<sup>†</sup>Total for Penn Group.

1914, WITH LOCATION, OWNERSHIP, ETC.—*Concluded.*

Number or name of level.	Operators.	Address of Home Office.
18th	American Boston Mining Co.	1300 Leader-News Building, Cleveland, Ohio.
9th	Breitung Hematite Mng. Co.	Marquette, Mich.
4th	Breitung Hematite Mng. Co.	Marquette, Mich.
	Republic Iron & Steel Co.	Youngstown, Ohio.
33d	Champion Iron Co.	Wolvin Building, Duluth, Minnesota.
3d	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
10th	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
2d	Empire Iron Co.	Rector Building, Chicago, Illinois.
	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
	Republic Iron & Steel Co.	Youngstown, Ohio.
	Mary Charlotte Mng. Co.	Marquette, Mich.
4th	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
5th	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
	Oliver Iron Mining Co.	Wolvin Building, Duluth, Minn.
	Oliver Iron Mining Co.	Wolvin Building, Duluth, Minn.
9th	Pittsburg & Lake Angeline Iron Co.	Cleveland, Ohio.
2d	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
3d	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
	Volunteer Ore Co.	1400 Alworth Bld., Duluth, Minn.
4th	Mary Charlotte Mining Co.	Marquette, Mich.
2d	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
9th	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
6th	Niagara Iron Mining Co.	North Tonawanda, N. Y.
Open pit	Niagara Iron Mining Co.	North Tonawanda, N. Y.
"Pasco"	Oliver Iron Mining Co.	Wolvin Bldg., Duluth, Minn.
Open pit	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
	Richmond Iron Co.	1300 Leader-News Bldg., Cleveland, Ohio.
8th	Jones & Laughlin Ore Co.	3d Ave. & Try St., Pittsburg, Pa.
16th	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
5th	Volunteer Ore Co.	1400 Alworth Bldg., Duluth, Minn.
10th	Washington Iron Co.	Marquette, Mich.
6th	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
6th	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
2d	American Mining Co.	Western Reserve Building, Cleveland, Ohio.
6th	Cleveland Cliffs Iron Co.	Ishpeming, Mich.
12th	National Tube Works Co.	Frick Bldg., Pittsburg, Pa.
17th	Chapin Mining Co.	Wolvin Bldg., Duluth, Minn.
	Penn Iron Mining Co.	1703 Morris Bldg., Philadelphia, Pa.
	Penn Iron Mining Co.	1703 Morris Bldg., Philadelphia, Pa.
8th	Loretto Iron Co.	1400 Fulton St., Chicago, Ill.
	Dessau Mining Co.	Care B. J. Clergue, Montreal, Que.
2d	Munro Iron Mining Co.	55 Erie Co. Bank Bldg., Buffalo, N. Y.
8th	Pewabic Co.	910 Wells Bldg., Milwaukee, Wisconsin.
18th	Penn Iron Mining Co.	1703 Morris Bldg., Philadelphia, Pa.
1st	Antoine Ore Company.	Republic Building, Youngstown, Ohio.

IRON ORE RESERVES OF MICHIGAN.

Range.	1911. <sup>1</sup>		1913. <sup>2</sup>		1914. <sup>3</sup>		1915. <sup>4</sup>	
	Developed. Tons.	Prospective. Tons.	Developed. Tons.	Prospective. Tons.	Developed. Tons.	Prospective. Tons.	Developed. Tons.	Prospective. Tons.
Gogebic county.....	18,296,721	13,308,279	23,813,191	7,754,388	23,765,158	21,113,192	33,764,457	12,838,990
Iron county: (Iron River District) (Crystal Falls District).....	7,924,687	25,689,155	13,249,683	47,536,233	13,337,913	45,045,227	19,258,369	42,961,778
Menominee: (Dickinson county).....	9,082,750	2,567,700	9,682,994	3,100,458	11,062,700	2,129,950	10,134,241	1,701,540
Marquette: (Baraga county) (Marquette county).....	36,228,742	56,473,068	34,692,034	51,529,275	33,095,467	47,919,718	28,629,708	50,235,260
State.....	71,542,900	98,038,202	81,437,902	109,920,354	81,261,238	116,208,087	91,786,775	107,737,568
Total.....	169,581,102		191,358,256†		197,469,325*		199,524,343‡	

\*Of date Jan. 1, 1914 in addition to which there was in stock 4,954,830 tons of ore, making a grand total of 202,424,155 tons  
 †Of date Jan. 1, 1913 in addition to which there was in stock 4,366,349 tons of ore, making a grand total of 195,724,605 tons  
 ‡Of date Jan. 1, 1915 in addition to which there was in stock 6,596,195 tons of ore, making a grand total of 206,120,538 tons  
 †Estimated by C. K. Leith for Board of State Tax Commissioners.  
 ‡Estimated by C. K. Leith and R. C. Allen for Board of State Tax Commissioners.  
 †Estimated by R. C. Allen and O. R. Hamilton for Board of State Tax Commissioners.

VALUE OF MICHIGAN IRON ORE SHIPMENTS 1914.<sup>1</sup>

Range.	Gross receipts.	** Beyond the "Mine" charges.	Net receipts (f. o. b. at mine).	Shipment. Tons. 1914.	Value per ton 1914.	Value per ton 1913.
Goegebic county.....	\$10,488,388 25	\$2,725,549 42	\$7,762,838 83	3,150,609	\$2 46	\$3 08
Iron River.....	5,081,766 92	1,506,001 84	3,575,765 08	1,988,860	1 80	2 08
Crystal Falls.....	2,899,452 73	712,239 20	2,187,213 53	1,156,452	1 89	2 38
Dickinson county.....	6,935,991 76	1,496,751 01	5,439,240 75	2,539,353	2 14	2 38
Marquette.....						
{ Marquette county }						
{ Baraga county..... }						
State of Michigan.....	\$25,405,599 66	\$6,440,541 47	\$18,965,058 19	8,835,274	\$2 14	\$2 52

\*Includes: 1. Rail freight.  
 2. Boat freight.  
 3. Cargo insurance.  
 4. Lower lake analyses.  
 5. Selling commissions.

1914 U. S. Production = 39,714,280 long tons.

Valued at \$71,905,079 or average price of \$1.81 per ton.

<sup>1</sup>From report of Appraiser of Mines to Board of State Tax Commissioners 1915.

TABLE SHOWING AVERAGE COST OF DELIVERY OF IRON ORE TO SALE POINTS FOR THE FIVE YEAR PERIODS, 1909-1913 AND 1910-1914.<sup>1</sup>

Range.	Number of mines.		Total tonnage.		Total cost.		Average cost per ton mined.	
	1909-1913.	1910-1914.	1909-1913. Mined.	1910-1914. Mined.	1909-1913.	1910-1914.	1909-1913.	1910-1914.
1 Marquette.....	39	40	19,299,746	18,624,664	\$51,428,569 14	\$45,426,953 75	\$2,58401	\$2,48757
2 Gogebic.....	29	31	16,480,150	17,371,091	47,037,450 88	48,353,983 05	2,86918	2,78358
3 Menominee.....	17	17	8,433,188	7,792,930	20,752,050 74	19,276,469 02	2,47565	2,47358
4 Iron River and Crystal Falls.....	33	37	13,751,488	12,260,693	31,910,664 20	30,840,372 40	2,35158	2,51038
State.....	118	125	57,964,581	56,049,378	\$151,137,734 96	\$143,897,779 12	\$2,63194	\$2,58294

<sup>1</sup>From report of Appraiser of Mines to Board of State Tax Commissioners, 1915.

APPRAISED VALUE OF MICHIGAN IRON MINES.<sup>1</sup>

Range.	Total acreage appraised 1915.	Previous appraisals.			1915 appraisal.		Combined value of mine and ore in stock.	Total tonnage in mine and in stock Jan. 1, 1915.	Assessed value per ton.
		1912.	1913.	1914.	Mine.	Ore in stock.			
Gogebic.....	5,987.00	\$27,226,300	\$25,849,873	\$34,667,028	\$29,563,056	\$4,814,736	\$34,877,792	48,242,119	\$0.71260
Iron county: (Iron River District) (Crystal Falls District).	8,087.00	15,359,664	20,978,709	21,275,945	18,178,474	2,878,445	20,856,919	63,342,684	.92927
Menominee:	3,877.60	7,240,625	6,641,925	6,413,003	4,074,448	1,831,995	5,906,443	12,571,939	.46981
Dickinson county.....	580.00	*	29,063,714	29,216,139	23,012,166	5,604,287	28,616,453	81,963,796	.....34913
Marquette: Baraga county.....	7,611.22	31,270,500							
Marquette county.....									
State.....	26,142.82	\$81,097,089	\$82,534,221	\$91,572,115	\$74,828,144	\$14,929,463	\$89,757,607	206,120,538	\$0.43546

<sup>1</sup>Ten per cent cut from 1911 assessment (approximate figure).  
<sup>2</sup>By Board of State Tax Commissioners.





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**PART II. NON-METALLIC MINERALS.**

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**R. A. SMITH.**

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## COAL IN MICHIGAN.

### MICHIGAN COAL BASIN.

#### Location and Extent.

The Michigan Coal Basin\* is the only coal field in the St. Lawrence drainage basin. It covers an area of about 11,000 square miles almost in the geographic center of the Southern Peninsula, extending from the central part of Tuscola county on the east to the western part of Newaygo county on the west and from the south central part of Roscommon and Ogemaw counties on the north to the central portion of Jackson county on the south.

The limits of the Coal Basin on the south and east have been approximately determined, but the margin is more or less irregular. On the north and northwest the boundary is more uncertain owing to the thick screen of surface deposits.

#### Surface Features.

The greater part of the Coal Basin lies in a low flat to gently undulating region bordered by a rim of higher and more broken land, broken on the northeast by Saginaw Bay and on the west by the valley of the Grand. The low flat portion of the interior basin, largely included in Saginaw Valley, has an elevation ranging from about 580 feet above sea level to 800 feet, and the higher undulating portions from 800 to 1,000 feet above sea level. The marginal higher broken tracts on the south and east rise from a height of about 1,000 feet to over 1,200 feet and those on the north and northwest from 1,000 to 1,600 feet, or respectively 400 to 600 feet and 400 to 1,000 feet above Lakes Huron and Michigan.

To a large extent the rim of high land is due primarily to an underlying rim of hard limestone (Bayport) and heavy sandstone (Marshall) of the Upper Mississippian. On the northeast this rock rim is breached by Saginaw Bay and on the northwest by an old pre-glacial valley which runs southwest from the head of the bay through northern Gratiot county and, veering to the west and then northwest through

\*See 22nd Ann. Rept. U. S. G. S., The Northern Interior Coal Field by A. C. Lane; also Vol. VIII, Pt. II Mich. Geol. Survey, Coal in Michigan by A. C. Lane.

Montcalm and Newaygo counties, enters the basin of Lake Michigan in western Mason and Manistee counties. The height of the rim was further accentuated in the Pleistocene period by a greater piling up of glacial debris along the rim than in the interior of the basin.

Though the rock surface is very uneven the mantle of drift is so thick that nearly everywhere it completely buries and conceals the coal measures. Southwest of a line from the mouth of Saginaw River to Grand Rapids the drift over the Coal Basin is generally 50 to 150 feet thick and only in a few places is it more than 200 feet. Northwest of this line, excepting in Arenac county, the drift is generally much thicker. Particularly is this true along the northern and northwestern margin and over the old pre-glacial valley previously noted where the glacial deposits are usually from 300 to 600 feet or more in thickness. This excessive thickness of drift has been an effective barrier to exploration and development.

The areas in the Coal Basin in which the drift is thin or absent are few and small. Most of the exposures of the Coal Measures are generally along stream courses, as along the Rifle River in Arenac county; the Cass and some of its tributaries near Tuscola, Tuscola county; the Flint near Flushing, Genesee county; the Shiawassee from Corunna, Shiawassee county, north to the Saginaw county line; the Cedar and the Grand from Williamston, Ingham county, to six miles below Grand Ledge, Eaton county; and the Grand and its tributaries around Dimondale and Eaton Rapids, Eaton county, Ionia, Ionia county and Jackson, Jackson county.

#### Accessibility.

The Coal Basin, especially the more developed southeastern half, lies in a thickly populated and rapidly growing industrial section of the state. Saginaw Bay breaks through the rim on the northeast and, with its estuary, Saginaw River, penetrates to the heart of the chief coal districts. Numerous manufacturing cities within or just outside the Basin, a natural water route to the Great Lakes, and a web of railroads radiating in every direction from Saginaw and Bay City, the chief coal centers, afford exceptional means for transportation and marketing.

#### Geology.

*Structure.*—In structure the coal field is that of a very flat synclorium with its longer axis extending north and south. The strata in general do not conform to the basin-like structure of the pre-coal measure formations but are nearly flat except for minor undulations and folds. Locally the strata are faulted but most of the observed

faults are small, having a throw or displacement of only a few inches or feet. Recently several faults of considerable size have been found and one in Bay County has a displacement of over 50 feet. Further observations may show that faults are much more prevalent in the coal series than formerly supposed.

*Character of the coal beds.*—The Coal Measures belong to the Upper Carboniferous or Pennsylvanian and consist of an upper productive portion called the Saginaw formation, and a lower barren one, the Parma sandstone.

The Saginaw formation is essentially a series of relatively thin beds of white shale or so-called fire clays, blue or gray and black shales, sandstones, and coal seams. Limestone is uncommon but locally thin seams of black band ore (siderite) and nodules of the same with zinc blend and iron pyrites occur in the coal or the associated shales.

In general the beds vary markedly in thickness and character within relatively short distances. Many of the beds are merely local lenses and few are continuous over any considerable area. Rapid variation is also characteristic of the coal seams. They generally undulate sharply and the rise and fall may be more than 20 feet in a few hundred feet. Locally the coal thins, pinches out, or grades into black shale, or is cut out entirely by sandstone. In some localities, however, the strata are predominately sandstone, in others, shale. The manner of the occurrence of coal is similar; in some areas there are several beds and in others none.

There is a more or less orderly sequence of the different strata. Generally white shale, the "fire" or "underclay" of miners, underlies the coal seams. The coal beds usually grade upward into so-called "cannel" or "bone" coal, or into black shale which in turn is followed by blue shale. Sandstone may succeed the shale or it may cut out the shale entirely and rest directly on the coal. The "fire" clays are locally very sandy or may be replaced by sandstone. These clays are not true fireclays since they do not possess particularly high refractory properties. The blue shales above the coal locally contain thin bands and nodules of siderite or iron carbonate. Some of the nodules contain sulphides of iron and zinc, and also kaolin. In some places, carbonaceous limestone replaces the blue shale. Sandstones, some of which are very massive, occur at any horizon but the repetition of the sequence upward—white shale or "fire clay", coal, "cannel" or "bone" coal, black shale, blue shale or limestone and in many places, sandstone, for each of the coal beds is characteristic.

The Parma is a white sandstone locally conglomeratic. The pebbles, generally of very white quartz are small and scattering. The Parma is to be considered as the basemental and shoreward facies of the

## MINERAL RESOURCES OF MICHIGAN.

overlying Saginaw formation, hence is not referable to a definite age. It is very persistent, being continuous over most of the Coal Basin and varies in thickness from about 170 feet to a feather edge. Locally, however, it is either absent or not present as a sandstone. Generally it yields an abundance of water, fresh near the margin and saline in the central part of the Basin. Its waters and brines contain a relatively high content of sulphates in comparison with the waters and brines of the Marshall sandstone below.

The Coal Measures were deposited upon the much eroded surface of the Grand Rapids group of the upper Mississippian, hence, in Michigan, there is a great unconformity separating the Mississippian and the Pennsylvanian. The erosion which followed the continental uplift in North America at the close of the Mississippian was so severe that deep valleys were carved in the land surface and in places these cut completely through the Bayport limestone and into or even through the Michigan Series below. The topography was much rougher than that of the present land surface. Along much of the southeastern side of the Coal Basin both the Bayport limestone and the Michigan Series appear to be absent, probably having been removed by erosion, or perhaps never deposited. As a consequence, the Parma sandstone locally rests directly but unconformably on the Marshall sandstone and, since the two are lithologically similar, they cannot be readily distinguished in well records. In northern Jackson and northeastern Calhoun counties and perhaps along the southeastern margin of the Coal Basin, coal measures were deposited in the bottom of valleys between ridges and hills capped with Bayport limestone and rocks belonging to the Michigan series.

*Thickness of the Coal Measures.*—The Coal Measures in some parts of the Coal Basin vary greatly in thickness within very short distances. This is due to two causes; first they were deposited upon a very uneven basement, the eroded surface of the Grand Rapids group, as noted above and, second, their upper surface has been heavily eroded. The Appalachian Revolution, the general upheaval at the end of the Pennsylvanian permanently converted the Michigan sea and its bordering swamps into a land surface probably a thousand feet higher at least than the present. During the ensuing long period of erosion, extending to the Pleistocene, the surface of Michigan was greatly dissected. A large drainage system trending to the west was developed in the central portion of the Southern Peninsula. The trunk stream, represented by the old pre-glacial channel previously noted, headed in Saginaw Bay, ran southwest into the center of the Coal Basin, and then, veering northwest through Manistee county, entered the valley or basin now occupied by Lake Michigan. The bottom of this channel at the head

of Saginaw Bay is nearly 200 feet below the surface of Lake Huron, over 325 feet in Gratiot county, and more than 700 feet below Lake Michigan in Manistee county, or over 100 feet below sea level. Numerous tributary streams dissected other parts of the Coal Basin producing a topography much rougher than that of the present land surface. The relief of the former surface was later more or less modified by the ice invasions of the Pleistocene which, in general, smoothed and rounded off the sharper topographic features.

The pre-glacial channels or "washouts," as they are termed by the miners, are now filled with drift, in places heavily water bearing. They cut out the coal beds and make mining uncertain and hazardous, particularly in the upper veins. In numerous instances, miners in driving entries have encountered these drift filled channels, sometimes with serious consequences from floods of water and quicksand. The amount of coal lost through pre-glacial erosion is very considerable but the data necessary for its calculation is insufficient. Few of the present rivers have cut through the thick mantle of drift, hence little coal has been lost through post-glacial erosion.

The troughlike deposits of the productive Coal Measures along the southern margin are very thin, being generally less than 100 feet in thickness. In the vicinity of Saginaw, the thickness is from 260 to about 325 feet, near Bay City, about 350 feet, and nearer the center of the Coal Basin at Mt. Pleasant and Midland, 410 and 525 feet respectively. Around the northern and northwestern border no drillings of reliable record penetrate completely through the productive Measures, hence little definite information is known of their average thickness in that part of the basin. In the central part of the Coal Basin, however, the thickness averages from 300 to 400 feet and probably nowhere is it much more than 500 feet.

*Occurrence of the coal.*—Coal does not occur in all parts of the Coal Basin. In several borings near the center of the Basin which penetrate completely through the coal bearing series neither coal nor black shale were found, the Saginaw formation being a series of sandstones and gray shales. Coal beds are apparently thicker and more numerous toward the margin of the Basin and tend to thin and disappear toward the center.

Thousands of test drillings have shown the presence of more than a dozen coal seams, most of which are too thin for mining under present conditions. Lane\* recognized seven distinct beds and made the following provisional series: Lower Coal, Lower Rider, Saginaw Coal, Middle Rider, Lower Verne, Upper Verne, and Upper Rider. Cooper†

\*Mich. Geol. Surv., Vol. VIII, Pt. II, p. 46.

†Mich. Geol. Surv., Ann. Rept. 1905, Bay County Report, p. 174.



added seven more, making fourteen in all, the complete series from bottom upwards being: Bangor Coal, Bangor Rider, Lower Coal, Lower Rider, Saginaw Coal, Middle Rider, Lower Verne, and Lower Verne Rider, Upper Verne and Upper Verne Rider, Salzburg Coal, and Salzburg Rider.

When it is considered that the whole coal series is characterized by extreme variation, that the fourteen or more coal seams occur in a section of barely 400 feet, that a given coal bed may rise or fall from 30 to 50 feet or more in a quarter of a mile, thicken, thin, or pinch out entirely in a few hundred feet, or split into two or more distinct seams, that many of the seams are merely local lenses or "pockets," that faults occur locally and that all of the above phenomena may be observed in a single mine, little weight should be attached to such an elaborate system of correlations. None of the coal beds extend continuously over the whole basin and few are continuous over any considerable part of it, and most of the areas in which the coal is of minable thickness are very small indeed. A rider of coal may or may not occur over each prominent coal seam but some beds have two or three lenses or so-called riders over them in the deeper troughs or valleys. The prominent coal seam of one locality may be unimportant in another and the main coal of the latter may correspond to a rider in the former. This reflects the transfer of favorable coal forming conditions from one part of the basin to another.

In the field of Wolverine Mine No. 3, Bay county, no less than ten seams of coal, not including the parts of split seams, occur in a section barely 175 feet in thickness, the seams averaging but little more than 15 feet apart. Deeper drilling in adjacent territory shows that there are at least three or four coal beds lower down. Of the upper ten veins only the so-called Verne, a split seam, is of minable thickness over any considerable area while some of the beds appear to be only thin lenses or "pockets" of coal of very limited extent. The "Verne Split" is continuous over a relatively large area, but it is variable in thickness, quality of the coal and number and distance apart of its members. Generally it is composed of two parts, the "Upper" and the "Lower Verne" seams, separated by a parting of "bone" coal or black shale. The bed in the field of Wolverine Mine No. 3 has a combined thickness of four to seven feet exclusive of the parting of shale. In turn either or both of the parts of the Verne may divide into a number of seams too thin for mining. Other coal beds exhibit this tendency to divide and it is certain that the "Verne" seams of one locality are not always related to the "Verne" of other localities.

It is generally impossible to satisfactorily correlate the thin lenses or "pockets" of coal encountered in different parts of the same field and

it is very difficult to trace accurately the thicker and more continuous beds even with closely spaced drillings on account of the great variation in thickness, character and elevation. In test hole No. 965, in the field of Wolverine Mine No. 3, the split seam between 180 and 183 feet occurs at the depth at which the "Verne" split might be expected and it was not definitely known that the group of splits between 191 and 196 feet was the "Verne" until a tunnel entry was driven through the coal at this point. It is possible that the upper split represents the "Upper Verne" and the lower the "Lower Verne." In one part of the Bliss mine at Swan Creek, Saginaw county, test holes showed a thin coal seam at the depth at which the main bed should occur and this part of the field was marked on the mine maps as unminable. Mining operations later showed that the main seam at this point was depressed into a trough and occurred at some distance below the thin seam in greater thickness than the average for the field.

In the field of Wolverine Mine No. 2 several faults have been discovered and one has been encountered in the mine workings for more than a quarter of a mile along the southern limit of the coal area, where the coal bed on the south of the fault line has been upthrown approximately 55 feet.

Since it is so difficult to make satisfactory correlations between coal seams in different parts of the same field, correlations between different fields and over long distances, where test holes are far apart, must be very uncertain and any elaborate system of coal seams based on such data can have very little value.

Of the fourteen or more distinct coal beds but four or five are known to contain areas of minable coal of any considerable size. The minable deposits are in the form of conclave lenses, though generally very irregular in outline and thickness. Most of the proven areas of minable coal contain less than 150 acres, only a few, more than 250 acres, and but two or three, more than 1,000 acres, and none exceed 2,000 acres.

Few of the deposits average more than three feet in thickness and some of them average only about 30 inches, which in Michigan appears to be the lower limit of average thickness at which coal can be profitably mined, unless other conditions are exceptionally favorable. Even in these thicker areas, the coal in places is inferior in quality, too thin for profitable mining, or is cut out entirely. The undulating floor of the coal basins results in a series of "rolls" or hills and valleys, which make haulage of coal and drainage of water to the central shaft difficult. The irregular form of the coal basins and the rapid variation in thickness and quality of the coal necessitate close and careful drilling in proving up a coal field. Some fields not sufficiently tested by drilling have

proved to be so "pockety" or variable in the quality of the coal that mining operations were unprofitable.

*Quality of the coal.*—All of the coals of Michigan are bituminous, but are of the domestic variety, non-coking for the greater part. In general the coals are of a lower grade than those of Ohio, Pennsylvania, and West Virginia, but the quality varies greatly not only in the different seams but also in the same seam within very short distances. The shallow and marginal beds are characteristically high in ash and sulphur and low in fixed carbon. Most of the coal formerly mined near Jackson, Jackson county; at Owosso and Corunna, Shiawassee county; and at Grand Ledge, Eaton county, contains from 2% to 14% of ash, 3% to 7% of sulphur, and only 40% to 45% of fixed carbon. Much of the coal mined in Bay county, is similar in that it is high in ash and low in fixed carbon. The sulphur, however, is low in some beds and very high in others, the range being from 1.5% to 6% and over. Some of the Bay county coals resemble lignite in their weak physical character, low specific gravity, and high content of volatile matter.

The coals mined in the vicinity of Saginaw and St. Charles, Saginaw county, are of better grade, the ash varying from 1% to 7%, the sulphur from 0.5% to 2%, and the fixed carbon from about 50% to 58%.

Many of the Michigan coals are characterized by a high content of moisture, the extreme range being from 2% to about 13%. The Bay county coals contain on the average from 3% to 8% and those from Saginaw county from 6% to over 12%. While most of the coals are high in volatile matter and many of them are coking coals, they are not used for gas and coke making. The coke is usually inferior, being light and friable; the sulphur injures the quality of both the coke and gas, and the moisture gives more or less trouble in the ordinary types of gas producers. The Saginaw and St. Charles coals, though low in sulphur, are largely non-coking and high in moisture.

Most of the coals are good to excellent domestic coals and fair to good steam coals. Unfortunately they are weak and friable and do not stand long shipment well or permit of stocking. On exposure to the action of the air, sun, and rain many of the coals are rapidly reduced to slack. Owing to these qualities there is also a relatively large amount of slack produced in mining, especially in thin veins when shot "off the solid."

The ash content in most seams varies greatly from place to place. In portions of some fields, the coal is so high in ash (see analyses) that it is not marketable. Such coal is popularly called "cannel" coal, but it is not true cannel as it burns with much smoke. At the bottom or top of coal beds there is locally an inch to a foot or more of shaly and, in places, pyritous coal termed by the miners "Black Jack"

or "dirty" coal. The early drillers failed to recognize this impure coal, and some of the areas of supposedly good coal have been found later to contain much "cannel" or "Black Jack" coal. This is the case in certain parts of the St. Charles coal field in Saginaw county.

The following analyses may be taken as fairly representative of the general character of Michigan coals. It is to be noted that the Bay county coals are in general lower in fixed carbon and higher in sulphur than those of Saginaw county.

## \*ANALYSES OF MICHIGAN COAL.

	Locality.	Mine.	Bed.	Sample.
	<i>Arenac county.</i>			
1	Rifle river, Sec. 3, T. 19, N. R. 4 E.	.....	Rifle river "cannel."	Air dried sample. ....
2	Rifle river, Sec. 3, T. 19, N., R. 4 E.	.....	Rifle river, lower seam.	Air dried. ....
	<i>Bay county.</i>			
3	Secs. 21 and 22, T. 14 N., R. 4 E.	Monitor. ....	.....	Run of mine sample. ...
4	Secs. 16 and 17, T. 14 N. R. 4 E.	Wolverine No. 2. ....	.....	Sample from car lots; commercial. ....
5	Secs. 16 and 17, T. 14 N., R. 4 E.	Wolverine No. 2. ....	.....	Lump coal; dried. ....
6	Secs. 16 and 17, T. 14 N., R. 4 E.	Wolverine No. 2. ....	.....	Lump coal; commercial.
7	Sec. 7, T. 14 N., R. 3 E. and Sec. 12, T. 14 N., R. 4. E.	Wolverine No. 3. ....	"Verne".....	Lump coal; air dried. ...
8	Sec. 30, T. 13 N., R. 6 E.	What Cheer. ....	.....	Run of mine; commercial.
	<i>Calhoun county.</i>			
9	Sec. 13, T. 2 S., R. 4 W.	Albion. ....	.....	Composite sample from sections from different Places. Includes slaty coal at top of seam. Dried.
	<i>Eaton county.</i>			
10	Grand Ledge. ....	Jenkins "drift".....	.....	Lump sample; dried.
11	Grand Ledge. ....	Jenkins "drift".....	.....	Selected lump sample; air dried.
	<i>Huron county.</i>			
12	Sebewaing. ....	Standard. ....	"Verne".....	Sample from stockpile; air dried.
	<i>Jackson county.</i>			
13	Jackson, Sec. 21, T. 1 N., R. 2 W.	New Hope. ....	.....	Selected lump. ....
	<i>Saginaw county.</i>			
14	Saginaw. ....	Pere Marquette No. 1. ....	.....	Section (92 inches) of main coal; natural. Same bed as Caledonia No. 3.
15	St. Charles. ....	Robt. Gage No. 1. ....	"Saginaw".....	Same field as Robt. Gage Mine No. 2. (New) 25 lb. sample; natural.
16	St. Charles. ....	Robt. Gage No. 1. ....	"Saginaw".....	Average of 13 analyses; air dried.
17	St. Charles. ....	Robt. Gage No. 1. ....	"Saginaw".....	Bone or cannel coal from top of seam, 8 inches; natural.
18	Saginaw. ....	Saginaw and St. Charles mines.	"Saginaw".....	Coal as marketed from Saginaw and St. Charles mines by the Consolidated Coal Co.
	<i>Shiawassee county.</i>			
18	Owosso. ....	Owosso. ....	.....	Section (33 inches) from main coal, natural.
19	Corunna. ....	Corunna. ....	.....	Average analysis of coal shipped.

\*A. C. Lane, 22nd Ann. Rept. U. S. G. S., p. 322; also Vol. VIII, Pt. II, Mich. Geol. Surv., pp. 110-119.

## \*ANALYSES OF MICHIGAN COAL.

Sp. Grav.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Heating power in B. T. U. (British Thermal units.)	Authority.
.....	11.35	35.80	41.10	11.87	5.84	.....	Sample through S. G. Higgins. Dickman and Mackenzie, analysts.
.....	3.60	40.00	55.40	1.00	.....	.....	
.....	4.60	38.70	48.40	8.30	1.20	12,732	Handy Bros. Mining Co.
.....	6.72	42.67	42.01	8.65	3.50	12,842	Analysts, Dickman and Mackenzie.
.....	.....	42.36	51.01	6.63	3.39	13,712	Wolverine Coal Co.
.....	7.72	39.08	47.09	6.11	3.11	12,653	Wolverine Coal Co.
.....	4.14	45.70	42.14	8.02	3.53	12,520	Wolverine Coal Co.
1.26	6.96	37.08	52.90	3.56	1.01	13,694	What Cheer Coal Co.
.....	.....	44.31	43.14	12.55	7.64	13,410	Analyst F. S. Kedzie. Sample contained 11.43 per cent of moisture, as received.
.....	.....	38.48	.....	10.14	4.61	.....	.....
.....	7.00	39.10	46.40	7.50	3.42	.....	Analyst, A. N. Clark.
1.34	6.09	39.54	46.06	8.26	5.72	12,767	Analyst, H. J. Williams.
1.24	5.93	46.59	44.64	2.84	3.07	13,580	Analyst, H. J. Williams.
1.269	10.15	33.14	53.95	2.76	1.10	12,726	Analyst, H. J. Williams.
1.285	7.79	34.74	52.58	4.89	1.01	12,836	Analyst, H. J. Williams.
.....	2.37	35.67	58.47	2.46	1.03	.....	Analyst, F. S. Kedzie.
.....	8.08	30.74	49.29	11.89	0.88	.....	Analyst, F. S. Kedzie.
.....	7.60	37.90	50.73	3.77	0.99	12,521	Analyst. Solvay Process Co., Syracuse, N. Y.
1.27	7.58	35.70	52.96	3.76	1.50	13,016	Analyst, H. J. Williams.
.....	6.33	35.46	45.45	12.04	.....	.....	

### Development.

*History of Coal Mining.*—Coal mining apparently began at Jackson, Jackson county, as early as 1835, and certainly at Grand Ledge, Eaton county, in 1839. Until 1910 small mines were operated in Jackson county in the small shallow trough-like deposits of coal which were generally not more than 200 or 300 yards wide and a few hundred in length. At the present time a similar deposit is being worked near Spring Arbor, Jackson county, and a larger deposit is being developed just across the county line in Calhoun county four miles north of Albion. At Grand Ledge two coal beds 18 to 26 inches in thickness formerly outcropped in places in the bed of Grand River and along the banks for more than a mile. Most of the easily accessible coal has been mined out, but at present small quantities are obtained from clay pits of tile companies, utilizing the so-called fire clays which are locally associated with the coal beds. Coal was mined near Corunna and Owosso, Shiawassee county, prior to 1860. The coal deposits thus far discovered in the vicinity of these places have been small and pockety and of poor quality, hence mining operations have been intermittent and largely unprofitable.

In 1858-9 an unsuccessful attempt was made to mine coal near Millets, Eaton county, and a successful one at Williamston, Ingham county in the early 60's. A small mine is still in operation at the latter place. About 1875 several small pockets of coal were discovered along Rifle River, Arenac county, and some cannel coal was mined. The deposits were near the margin of the Coal Measures and were without proper roof, which together with much water and lack of transportation facilities discouraged further exploration and development.

In 1861 coal was discovered at Bay City by William Walker in drilling a salt well. The discovery created considerable interest at the time, but since there was an abundance of cheap wood fuel from the lumber industry nothing came of the discovery. In the early 90's coal was discovered in Saginaw and Bay counties, but it was not until 1897 that the real growth of the coal industry began. Numerous mines were opened up, chiefly in the vicinity of St. Charles, Saginaw, and Bay City. A few years later coal mining began in Huron, Tuscola, and Genesee counties, and in 1913 in Calhoun county. The production grew from about 90,000 tons in 1896 to more than 2,000,000 tons in 1907, the maximum amount in the history of the industry.

*Mining conditions.*—The irregular form of the minable coal areas and the variable thickness and quality of the coal makes systematic plans of mining difficult or impracticable to carry out. Some of the coal basins are very irregular in form, being made up of several subordinate basins. For ease in handling the coal and water the shaft should

be sunk in the lowest part of the basin but the uneven bottom makes the location of this uncertain without thorough drilling. Even when located at the most advantageous point the numerous hills and valleys are so pronounced that it is difficult to drain the water to the central shaft. In some mines auxiliary pumps are installed at various points to pump the water over the "rises" or to the surface through drill holes. To take advantage of gravity in hauling the coal to the shaft the entries follow the troughs in the coal bed as far as possible but heavy grades cannot always be avoided and auxiliary power must be provided at these points. The areas of "cannel," "Black Jack," or thin coal are very irregular in extent and mining plans must be constantly changed to meet the varying conditions. As a consequence maps of the workings of some mines resemble gigantic spiders.

Faults have been observed in a number of mines but most of faults are very small, the vertical displacement being measured in inches or two or three feet at most. In the Wolverine Mine No. 2 a large fault has been discovered in the workings for more than a quarter of a mile along the south side of the field. The coal bed on the south side of the fault has been upthrown a vertical distance of 55 feet along a fault plane having a hade of about  $35^{\circ}$  to the south. Such faults are apparently very rare in the Coal Measures of Michigan and most of the faults are so small that they interfere but little with mining operations.

Practically all of the coal seams except at Grand Ledge and Williamston are below the water table and largely in artesian territory, hence the most of the mines are very wet. The water comes in through the roof, the foot wall or both, or from the coal seam itself. Water has caused the abandonment of several mines and it is a serious menace to the successful operation of some of the present mines. The drift generally contains thick beds of quicksand and gravel, heavily water bearing. This makes shaft sinking very costly and uncertain. Several shafts have been lost owing to the quicksands and floods of water encountered. The erosion channels or "washouts" which are numerous in Bay county, are very wet and are a source of great danger. Several mines have been flooded, some permanently and such channels were encountered in mining. In general, water is very troublesome and its control and removal forms an important item in mining costs, especially in summer when the mines are practically idle.

Most of the proven areas of minable coal in Michigan have an average thickness of only about three feet, therefore the maximum yield of coal per acre which can be expected is relatively small. It follows that a larger acreage is required for a tonnage sufficiently great to warrant mining operations. The rapid variation in the thickness of the coal beds gives rise to local areas of thin coal, perhaps too thin for profitable



mining. The coal in such areas is not only lost but much expense is entailed by the extra dead work of driving entries through or around these areas. Areas of "bone," "cannel," or "black jack" coal further reduce the total expected tonnage. In general the greater acreage, the irregular form of the coal bodies, their variable thickness and the uneven bottom, necessitate longer and more numerous entries, greater trackage, and more dead work to win a given amount of coal than in Ohio, West Virginia, or Pennsylvania. The roof is generally weak and treacherous requiring heavy and costly timbering to support it. In places the shale roof slacks upon exposure to the air and breaks into innumerable fragments. The cost of sustaining such a roof is usually prohibitive. The "fire" or "underclays" beneath the coal likewise slack upon exposure to air and water and become soft and plastic. The pressure from the overlying strata forces them up into the workings, causing constant trouble and expense through heaving the tracks and choking the entries.

*Mining Costs.*—The thick surface materials, usually heavy water bearing, makes shaft sinking in Michigan very expensive. In Ohio a shaft may be sunk and a small plant built and equipped for \$15,000 to \$20,000 but in Michigan a shaft, mine-plant and equipment of similar capacity would generally cost from \$40,000 to \$50,000 or even more. The amount of dead work—entry driving, timbering, track laying, cutting through bars and areas of unminable coal, etc. is greater than in competitive fields. The expense of pumping and keeping the mines in running order during the idle season is excessive. The wage scale is higher and is interpreted more liberally for dead work than elsewhere. In addition the mines work but six eight hour shifts per week and are practically idle during part of the summer. All this tends to make mining costs very high, or two or three times as high as in Ohio and West Virginia. To make matters worse the relatively inferior quality and weak nature of Michigan coals demand that they shall sell at lower average prices than the firmer higher grade coals from bordering states.

The future of coal mining in Michigan depends largely upon the ability of the operators to reduce the present excessive mining costs and to increase the average sale price by improving the average quality of the coal through better methods of mining. The following table shows that the average daily wage increased from \$2.34 in 1900 to \$3.49 in 1913, and that the average cost of mining a ton of coal correspondingly has increased during the same period from \$1.387 to \$1.977. (See table of production and mining costs.)

*Methods of mining.*—The room and pillar double entry system of mining is the principal one used in Michigan. Attempts have been made to use the long wall system but it was found impracticable on

account of the weak and treacherous roofs in most of the mines, and the difficulty of adapting the long wall mining scale of other states to the scale conditions in Michigan.

Until 1898 all of the coal was mined by hand or "shot off the solid." The latter method is very wasteful particularly in Michigan where the seams are thin and the coal weak. The inordinately heavy charges of powder required in "shooting off the solid" shatters the coal producing much fine coal or slack and rendering the lump coal so friable that it disintegrates badly in handling and transportation. In addition the heavy charges shatter the weak roofs, which become a source of trouble and great danger.

In 1898 seven coal cutting machines were introduced into Michigan and they were so successful that eighteen more were brought in the following year. At first considerable difficulty was experienced, however, in adapting the machines, particularly the chain breast types to thin seams and to the weak roofs which require the timbering to be kept up close to the face. As a result there were only 46 machines in use in 1903, five years after their introduction. In the next five years, however, the number of machines increased to 120, but with the decline in coal production, which began in 1908 and has continued to the present, the number of machines also decreased. In 1912 and 1913, however, with the introduction of the short wall type of machine the number increased to 126 and 130 respectively.

In 1903, 13.2 per cent of the total production of coal was mined by machines and in 1908 the percentage increased to 29.2 per cent, in 1910 to 45.5 per cent, in 1912, to 52.7 per cent and in 1913, to 70 per cent. While nearly 30 per cent of the coal is still shot off the solid, the wonderful increase in the percentage of machine mined coal during the last three years is indicative of the recognition on the part of the operators of the importance of using efficient methods of mining. If the present rate of increase in machine mined coal is maintained, coal mining in Michigan will soon be conducted as efficiently as in West Virginia, Pennsylvania, and Ohio, where the per cent of coal shot from the solid in 1913 ranged from less than one per cent in the first state to 3.7 per cent in Ohio.

Up to 1904, the machines were chiefly of the pick or puncher type but after this the chain breast machine came into prominence. They never became so widely used as the puncher type since they are not well adapted to thin coal seams and to the close timbering required by the weak and treacherous roofs. A few long wall machines were experimentally used in a number of mines but they were impracticable as their use requires more room at the face than the chain breast type. In 1910 the short wall machine was introduced with such success that it threatens to displace all other types

Pick machines are operated by air and the difficulty and trouble of laying air pipes forms a serious objection to their use. The chain breast and short wall machines are electrically operated and the work of stringing the necessary power wires is comparatively easy. The latter machines on account of their compactness and ease of manipulation are especially adapted to the room and pillar method and to the close and narrow workings obtaining in most of the mines in Michigan.

Formerly so much slack was produced that it became a drug on the market. Modern manufacturing concerns, equipped with mechanical stokers, preferred to use slack from Ohio, West Virginia, and elsewhere which was of better quality and could be obtained very cheaply. To improve the quality of the slack a washery was established at Saginaw by the Consolidated Coal Company to wash the slack from their mines. This so improved the quality that the present demand for Michigan washed slack far exceeds the supply. Much more coal could be recovered if washing plants were established by the other large operators.

*Prospective Development.*—Most of the proven coal areas are in Bay and Saginaw counties, but Genesee and Tuscola counties are known to possess large reserves of minable coal. The largest group of developed and undeveloped coal areas occurs between Midland and Bay City, the second most important group is between Saginaw and St. Charles, a third in the northern part of Bay county, and a fourth in the vicinity of Flint, Genesee county. Important areas have also been located in northeastern Tuscola county.

Coal beds from three to five feet in thickness have been struck in many places around the southern margin of the Coal Basin, but as yet little systematic drilling has been done to determine the extent of such beds except near Albion. In this part of the Basin the beds are shallow and the drift is thin, but the coal apparently occurs principally in troughs of very limited extent. Coal beds probably containing areas of minable coal occur in the northwestern half of the Coal Basin, but the great depth of the drift and the abundance of water and quicksand are effective barriers against exploration or mining operations in this region.

Mines have been opened in most of the known coal deposits in Saginaw county but only a few of the proven coal areas in Bay county have been developed as yet. There are a dozen or more of undeveloped coal areas between Midland and Bay City and new mines will probably be opened in these as fast as the present mines become exhausted. The development of the reserves in the northern part of Bay county will probably be slower as they are relatively distant from means of transportation.

From the fact that the local price of coal is generally much higher than that of competitive markets small isolated mines supplying

merely the local trade have been operated with success at various times and places as at Jackson, Williamston and Grand Ledge. A small mine is being opened at the present time near Albion, Calhoun county, to supply local markets.

#### Markets.

From the central position of the Coal Basin Michigan coals should command the markets of the state with the exception of the extreme southern portion in close proximity to the Ohio and Indiana fields. In the portion of the state north of a line from Port Huron, Lansing, and Grand Rapids Michigan coal has a natural protection in differential freight rates varying from \$.75 to \$1.40 per ton for coals from Ohio fields and about 25 cents per ton more for coals from West Virginia. The cost of mining coal in Michigan, however, is upwards of \$1.00 per ton more than in Ohio and West Virginia and this counterbalances most of the advantage in lower freight rates. In addition much of the Michigan coal is inferior in grade to the average from those states, hence Michigan coal must compete at a lower average price. From these facts the market for Michigan coals is restricted chiefly to the Coal Basin itself and to the northern portions of the state.

#### Production.

Although coal mining began as early as 1835 it was not until 1860 that any records were kept. In that year Michigan is credited with an output of 2,320 tons. Ten years later the production had increased to a little over 28,000 tons, and in 1880 and the two following years it exceeded the 100,000 ton mark. After this there was a sharp decline, less than 37,000 tons being mined in 1884. The production gradually increased until 1895 when the 100,000 ton mark was again passed. In 1897 with the discovery and opening of the Saginaw and Bay county fields the production was nearly a quarter of a million tons. Two years later it was nearly 625,000 tons, and in 1901 it approached 1,250,000 tons, but a strike of the miners in Saginaw Valley in 1902 caused a sharp decrease to less than 1,000,000 tons. In 1906 another strike caused a decline in production but in the following year the maximum output of 2,035,858 tons was attained. In 1908 a pronounced decline in production set in and this continued until 1912 when the output totalled only 1,206,230 tons. In 1913 there was a slight increase, the production being 1,231,786 tons.

According to the State Department of Labor, nearly complete figures for 1914 give a total production of 1,153,869 tons and it appears very probable that the final figures will not exceed 1,161,000 tons.

MINERAL RESOURCES OF MICHIGAN.

PRODUCTION OF COAL AND COST OF MINING, ETC., IN MICHIGAN BY COUNTIES AND MONTHS FOR 1914.

County.	January.										February.										March.										
	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mine units of powder.	Number of kegs of powder used.	Number of tons mined.	Number of tons of anthracite mined.	Total number of tons of coal.	Average cost per ton.	Total amount of coal.	Number of tons.	Number of tons of anthracite.	Total number of tons of coal.	Average cost per ton.	Total amount of coal.	Number of tons.	Number of tons of anthracite.	Total number of tons of coal.	Average cost per ton.	Total amount of coal.								
Bay.....	7	1,194	8	22.1	\$3.52	\$93,148.18	7	1,427	17,419	41,440	\$2.80	\$48,808	41,440	30,008	71,448	\$2.19	\$154,656	8	1,205	8	20.4	\$3.89	\$30,758.20	8	1,300	14,666	43,853	58,519	\$2.07	\$121,372.40	
Saginaw.....	8	922	8	22.8	3.23	67,806.80	8	1,474	19,450	30,068	1.88	\$56,118	30,068	20,118	50,186	1.82	\$90,304	8	979	8	22.3	3.28	71,784.70	8	1,388	18,409	50,204	63,703	1.82	\$117,908.74	
Other counties..	6	230	8	23.3	2.69	14,420.00	8	350	4,478	2,114	2.86	\$5,869	2,114	0,000	2,114	2.64	\$5,593.16	7	220	8	22.0	3.14	15,603.70	7	322	4,491	3,478	7,969	2.64	\$21,000.16	
Total.....	21	2,352	8	22.4	\$3.32	\$175,465.74	18	3,200	41,847	74,621	115,478	\$2.01	\$200,000.00	74,621	50,126	124,747	\$2.01	\$250,000.00	17	2,410	8	19.0	\$5.41	\$156,443.04	17	2,861	31,497	70,968	102,465	\$1.01	\$102,500.00
Bay.....	7	1,187	8	17.5	\$3.60	\$74,906.26	7	1,130	10,465	36,067	\$2.20	\$46,032	36,067	28,000	64,067	\$1.75	\$112,034.00	8	1,074	8	20.3	3.25	64,273.10	8	1,300	16,370	38,126	54,496	\$1.75	\$94,000.00	
Saginaw.....	8	974	8	20.3	3.21	17,263.68	8	413	4,602	1,761	2.74	\$4,761	1,761	0,000	1,761	2.74	\$4,800.00	7	240	8	21.6	3.21	17,263.68	7	322	4,602	3,478	8,080	2.74	\$22,000.00	
Other counties..	7	240	8	21.6	3.21	17,263.68	8	413	4,602	1,761	2.74	\$4,761	1,761	0,000	1,761	2.74	\$4,800.00	7	240	8	21.6	3.21	17,263.68	7	322	4,602	3,478	8,080	2.74	\$22,000.00	
Total.....	22	2,410	8	19.0	\$5.41	\$156,443.04	17	2,861	31,497	70,968	102,465	\$1.01	\$102,500.00	70,968	50,126	121,094	\$1.01	\$121,000.00	17	2,410	8	19.0	\$5.41	\$156,443.04	17	2,861	31,497	70,968	102,465	\$1.01	\$102,500.00
Bay.....	8	1,205	8	20.4	\$3.89	\$30,758.20	8	1,300	14,666	43,853	\$2.07	\$121,372.40	43,853	30,008	73,861	\$2.07	\$151,380.80	8	1,205	8	20.4	\$3.89	\$30,758.20	8	1,300	14,666	43,853	58,519	\$2.07	\$121,372.40	
Saginaw.....	8	979	8	22.3	3.28	71,784.70	8	1,388	18,409	50,204	1.82	\$117,908.74	50,204	20,118	70,322	1.82	\$128,026.48	8	979	8	22.3	3.28	71,784.70	8	1,388	18,409	50,204	63,703	1.82	\$117,908.74	
Other counties..	7	220	8	22.0	3.14	15,603.70	7	322	4,491	3,478	2.64	\$5,593.16	3,478	0,000	3,478	2.64	\$9,086.32	7	220	8	22.0	3.14	15,603.70	7	322	4,491	3,478	7,969	2.64	\$21,000.16	
Total.....	23	2,404	8	21.4	\$3.46	\$178,436.69	18	2,910	37,656	82,505	120,261	\$1.01	\$120,261.00	82,505	50,126	132,631	\$1.01	\$132,631.00	18	2,404	8	21.4	\$3.46	\$178,436.69	18	2,910	37,656	82,505	120,261	\$1.01	\$120,261.00

April.

Bay.....	7	889	8	14.1	\$3 59	\$45,109 83	6	600	8,624	22,464	31,088	\$2 11	\$65,665 09
Saginaw.....	7	968	8	18.8	2 95	53,779,99	7	930	9,260	31,782	41,042	2 01	82,695 62
Other countries..	6	209	8	18.6	3 21	12,481 28	1	78	1,480	1,270	2,750	4 66	12,825 48
Total.....	20	2,066	8	16.7	\$3 22	\$111,371 10	14	1,608	19,364	55,516	74,860	\$2 15	\$161,186 19

May.

Bay.....	7	851	8	18.7	\$3 54	\$56,401 79	6	815	10,292	26,746	37,038	\$2 05	\$76,274 98
Saginaw.....	7	951	8	18.4	3 36	58,891 54	7	1,032	9,621	30,509	40,130	1 91	76,931 59
Other countries..	6	192	8	20.5	3 50	13,787 62	1	74	726	3,327	4,053	3 01	12,184 25
Total.....	20	1,994	8	18.7	\$3 46	\$129,080 95	14	1,921	20,639	60,582	81,221	\$2 03	\$165,390 82

June.

Bay.....	6	638	8	14.0	\$3 52	\$31,054 64	5	634	9,361	11,542	20,903	\$2 12	\$44,449 04
Saginaw.....	6	837	8	13.8	3 46	40,069 22	6	616	8,951	22,240	31,191	1 92	69,161 53
Other countries..	4	175	8	26.9	3 14	14,810 16	1	123	1,745	5,387	7,132	2 41	17,171 14
Total.....	16	1,650	8	15.2	\$3 42	\$85,950 52	12	1,373	20,057	39,169	59,226	\$2 05	\$121,781 71

July.

Bay.....	5	469	8	18.9	\$3 43	\$30,346 56	3	563	8,219	13,680	21,899	\$1 44	\$41,619 27
Saginaw.....	7	889	8	15.3	3 59	48,941 73	7	768	11,196	26,430	37,626	1 84	69,254 78
Other countries..	4	191	8	24.7	3 01	14,233 12	1	99	3,161	3,031	6,212	2 39	14,860 47
Total.....	16	1,549	8	17.6	\$3 36	\$93,521 43	11	1,430	22,566	43,141	65,737	\$1 75	\$125,734 52

Adapted from statistical data, compiled and published in the Annual Report of the State Department of Labor for 1914.

MINERAL RESOURCES OF MICHIGAN.

PRODUCTION OF COAL AND COST OF MINING, ETC., IN MICHIGAN BY COUNTIES AND MONTHS FOR 1914. Continued

County.	Number active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	August.		Number of mines using powder.	Number of kegs of powder used.	Number of tons mined.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of coal.
						Aggregate amount paid in wages.	Number of tons of coal.								
Bay.....	8	1,180	8	15.9	\$3 51	\$66,017 58	7	878	15,613	25,416	41,029	41,029	\$2 21	\$90,080 00	
Saginaw.....	7	929	8	22.4	3 43	71,527 80	7	1,278	15,019	39,405	54,424	54,424	1 75	95,500 00	
Other counties..	5	193	8	24.8	3 16	15,152 95	1	115	2,461	4,355	6,816	6,816	2 34	15,025 38	
Total.....	20	2,302	8	19.2	\$3 45	\$152,699 33	15	2,271	33,093	69,176	102,369	102,369	\$1 97	\$202,404 06	
September.															
Bay.....	7	1,048	8	20.3	\$3 41	\$72,728 40	7	1,275	15,881	33,548	49,429	49,429	\$2 03	\$100,785 77	
Saginaw.....	8	942	8	20.7	3 33	64,966 08	7	1,173	13,514	33,743	47,257	47,257	1 70	83,587 14	
Other counties..	5	207	8	23.6	3 06	14,015 42	1	134	2,470	4,127	6,606	6,606	2 21	14,822 30	
Total.....	20	2,197	8	20.7	\$3 37	\$152,609 90	15	2,582	31,871	71,418	103,292	103,292	\$1 92	\$198,805 17	
October.															
Bay.....	8	1,162	8	20.9	\$3 38	\$82,142 06	7	1,301	18,720	37,333	56,053	56,053	\$1 04	\$108,823 88	
Saginaw.....	8	967	8	21.7	3 03	63,666 20	8	1,281	15,963	31,990	47,953	47,953	2 21	106,321 76	
Other counties..	5	220	8	20.5	3 50	16,174 81	1	127	4,488	2,133	6,621	6,621	2 12	14,010 01	
Total.....	21	2,340	8	21.5	\$3 20	\$161,983 07	16	2,709	39,171	71,466	110,627	110,627	\$2 07	\$220,165 10	

NON-METALLIC MINERALS.

November.

Bay.....	8	1,196	8	19.6	\$3 57	\$83,803 93	7	1,235	15,814	40,141	55,965	\$1 99	\$111,415 54
Saginaw.....	8	996	8	19.0	3 31	62,947 87	6	1,064	13,270	30,960	44,239	1 91	82,516 41
Other counties..	5	219	8	23.7	3 13	16,170 62	1	108	4,843	2,171	7,014	2 18	15,313 54
Total.....	21	2,411	8	19.7	\$3 43	\$163,622 42	16	2,437	33,936	73,272	107,208	\$1 97	\$211,245 49

\*December.

Bay.....	6	1,078	7.8	23.4	\$3 56	\$89,806 04	6	1,093	15,159	47,857	63,016	\$1 79	\$113,007 85
Saginaw.....	8	815	7.9	20.3	3 33	65,861 84	8	1,020	6,734	41,193	47,927	1 72	82,645 09
Other counties..	3	19	8	26.7	2 95	1,501 00			257		257	6 74	1,736 45
Total.....	17	2,072	7.9	24.7	\$3 49	\$157,168 88	14	2,113	22,150	89,050	111,200	\$1 78	\$197,389 39
Average per mo.....		2,146	8.0	19.9	\$3 35			2,400	29,487	66,712	96,155		\$191,680 11
State total.....						\$1,717,352 71		27,561	353,310	800,550	1,153,869	\$1 99	\$2,298,960 49
Total for Cos.													
Bay.....						\$816,223 58		12,356	160,223	393,177	540,319		\$1,102,010 27
Saginaw.....						734,306 87		13,353	157,864	387,309	545,165		1,020,615 89
Other counties..						166,804 36		1,852	35,231	33,154	68,385		176,334 33

\*Figures incomplete for December.



MINERAL RESOURCES OF MICHIGAN.

PRODUCTION, COST OF MINING, AND VALUE OF COAL IN MICHIGAN, 1900-1914

Year.	Number active miners	Average number per month	**Average daily wages.	Total tons of coal mined.	Total cost of coal mined.	Average cost per ton.	**Total value of coal mined.	Total value of coal mined (from reports)	**Average price per ton	Price paid per ton
1900	31	1,676	\$2 34	871,388	\$1,909,328	\$1 387	849,473	\$1,930,888	\$1 483	\$0 000
1901	30	1,844	2 44	1,016,498	1,443,415	1 410	1,211,211	1,758,904	1 419	007
1902	32	1,616	2 75	890,987	1,283,342	1 437	1,064,718	1,658,192	1 514	387
1903	34	3,014	2 91	1,601,984	2,529,027	1 579	1,907,619	2,707,837	1 370	000
1904	33	2,733	3 01	1,408,373	2,266,068	1 609	1,342,840	2,424,085	1 806	007
1905	38	2,776	2 96	1,413,307	2,244,434	1 588	1,478,211	2,612,607	1 705	117
1906	38	2,106	2 40	1,327,385	2,003,480	1 509	1,346,328	2,432,401	1 808	974
1907	37	2,807	3 24	1,911,301	2,162,837	1 125	1,635,858	2,660,833	1 628	184
1908	36	2,117	3 02	1,842,278	2,080,250	1 137	1,635,610	2,322,004	1 411	184
1909	36	2,907	2 93	1,736,373	2,865,083	1 650	1,784,002	3,190,361	1 793	143
1910	34	2,471	3 07	1,482,276	2,698,342	1 704	1,684,007	3,680,771	1 900	000
1911	32	2,530	3 39	1,396,285	2,023,374	1 447	1,476,074	3,701,401	1 801	004
1912	29	1,866	3 49	1,199,768	2,170,376	1 809	1,201,230	3,300,401	1 860	000
1913	24	2,076	3 49	1,158,163	2,350,500	1 977	1,251,780	3,466,327	1 663	010
1914	23	2,146	3 35	1,153,869	2,285,281	1 990				

\*Compiled and adapted from reports of State Coal Mine Inspector, Ann. Repts. State Department of Labor.

\*\*For year beginning Dec. 1 and ending Nov. 30.

\*\*\*From Mineral Resources of United States, U. S. G. S.

NON-METALLIC MINERALS.

PRODUCTION OF COAL BY COUNTIES, 1899-1914.

	Bay.	Eaton.	Ingham.	Jackson.	Saginaw.	Shla- wassee.	Tuscola.	Other counties.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
*1914..	540,319	82	1,376	1,287	545,165	903	†45,105	.....
*1913..	579,123	155	2,953	457	521,848	2,170	31,480	..... 453
*1912..	607,740	374	3,874	.....	489,198	4,532	59,252	.....
1911..	766,470	100	.....	.....	667,282	13,000	66,427	..... 19,000
1910..	766,470	100	.....	.....	667,282	.....	.....	..... 101,215
1909..	822,577	558	.....	1,500	859,434	.....	.....	..... 100,623
1908..	782,503	2,286	.....	5,539	999,338	.....	.....	..... 45,353
1907..	962,574	5,982	.....	5,645	1,047,927	.....	.....	..... 13,730
1906..	481,398	18,507	.....	8,658	835,475	.....	.....	..... 2,300
1905..	544,154	4,058	.....	9,196	915,803	.....	.....	.....
1904..	410,634	9,057	.....	16,860	906,289	.....	.....	.....
1903..	325,021	7,393	.....	23,307	1,011,898	.....	.....	.....
1902..	248,645	8,800	.....	23,889	670,304	.....	.....	..... 13,400
1901..	253,821	4,803	.....	20,288	938,042	.....	.....	..... 24,284
1900..	190,814	4,530	.....	23,317	601,112	.....	.....	.....
1899..	104,588	3,421	.....	21,600	455,607	.....	.....	..... 39,492

\*Compiled from Annual Report of State Department of Labor.  
 †Incomplete returns, tonnage approximate.

## PRODUCTION OF COAL IN MICHIGAN, 1860-1914, IN SHORT TONS.

Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.
1860	2,320	1871	32,000	1882	135,339	1893	45,979
1861	3,000	1872	33,600	1883	77,296	1894	70,022
1862	5,000	1873	58,000	1884	36,712	1895	112,322
1863	8,000	1874	58,000	1885	48,178	1896	92,862
1864	12,000	1875	65,500	1886	60,434	1897	252,692
1865	15,000	1876	62,500	1887	71,461	1898	315,722
1866	20,000	1877	66,197	1888	81,497	1899	1,584,692
1867	25,000	1878	69,187	1889	61,497	1910	1,584,692
1868	28,000	1879	85,322	1890	74,857	1911	1,476,974
1869	28,000	1880	82,013	1901	74,857	1912	1,476,974
1870	29,980	1881	100,800	1902	80,307	1913	1,153,669
	28,150		112,000	1892	77,490	1914	1,153,669

\*Approximate, returns incomplete. Report of State Coal Mine Inspector, State Department of Labor.

## LIMESTONE.

The limestone industry in Michigan has made a relatively rapid growth since 1899, but the period of most rapid growth was after 1904. In 1899, the total value of the product including lime was \$281,769, while in 1914 the total value exclusive of lime, which amounted to \$287,648, was \$1,457,961. The gain in 1914, however, was small, the increase amounting to only \$49,258 as against \$269,143 in 1913. The cause of the small increase in 1914 was due to the general business depression throughout the country.

The chief increases were in stone for blast furnace flux, sugar making, and fertilizer; the chief decreases, in the output of crushed stone for road making and railroad ballast, and of stone for the manufacture of soda ash. The large increase in flux stone made in spite of the depressed condition of the iron trade is chiefly owing to the fact that large deposits of high grade limestone near water transportation and very suitable for blast furnace use have been extensively developed in the northern part of the state in the past three or four years, and this stone is successfully invading the flux stone market formerly dominated by limestone from other states. The use of pulverized or ground limestone as a fertilizer and soil rectifier is growing very rapidly and the increase in value of this product in 1914 was more than 57 per cent.

Twenty-five quarries were in operation in 1914. Some quarries, chiefly small ones, were idle but the loss was compensated for by the opening of new or the reopening of old quarries. The crushing plant of the France Stone Co. of Monroe was destroyed by fire the first of the year, but the company rebuilt at once, and now have a new plant completely equipped with modern machinery for producing crushed stone for roadmaking, railway ballast and concrete. The Great Lakes Stone & Lime Co. were unable to complete their crushing plant at Rockport before the close of the 1914 season, but according to reports they will begin active operations in 1915. Their stone is very high calcium limestone, bituminous and very fossiliferous. The Cheboygan Limestone Products Co. opened a quarry near Mackinaw City in high calcium beds belonging to the Dundee limestone.

Owing to the purity and favorable situation of the limestone deposits near water, in which the more recent and larger quarries have been opened, it is very probable that the limestone industry in Michigan will continue to make a steady and rapid growth. With the return of more normal conditions in the iron industry, the season of 1915 promises to be the greatest in the history of the limestone industry in Michigan.

During a portion of the field season of 1913 and 1914, R. A. Smith of the State Geological Survey made an examination of the limestone resources of the state and a complete report is now in preparation.

NON-METALLIC MINERALS.

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PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1914.

Year.	Rough building. Value.	Dressed building. Value.	Paving. Value.	Curbing. Value.	Flagging. Value.	Rubble. Value.	Riprap. Value.	Crushed stone.	
								Road making. Value.	Tons.
1899	\$30,290	*	\$62,815				\$1,111		
1900	32,382	*	105,266				1,790		
1901	47,785	*			\$380	\$5,098	*		\$31,605
1902	58,765	*		\$489	200	3,710	5,700		56,263
1903	36,528	*	49,000	250	5,150	2,800	2,405		61,243
1904	32,071		37,665			744	1,568		58,655
1905	17,071	805		160		1,204	1,204		112,113
1906	3,368	641	90,733	75		4,654	1,204		176,437
1907	12,220	100	56,500			1,433	1,234		136,706
1908	7,276		10,825	300	100	15,907	1,574		182,500
1909	4,450	7,445				1,572	3,615		192,902
1910	3,522		35,500			2,265	308		110,164
1911	7,526					365	359	224,307	113,574
1912	9,607					360	610	603,653	295,449
1913	8,274					3,311		532,311	266,316
1914	3,537					1,651	6,727	505,133	242,839
<b>Total</b>	<b>\$324,793</b>					<b>\$43,931</b>	<b>\$28,750</b>		<b>\$1,873,895</b>

\*Included in total for year.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1914.—Continued.

Year.	Crushed stone.				Concrete.	For blast furnace flux.		To sugar factories. Value.	To alkali works. Value.
	Railroad ballast.					Tons.	Value.		
	Tons.	Value.	Tons.	Value.					
1899.....									
1900.....		\$18,200		\$75,643		\$27,512			
1901.....		40,810		49,430		3,200			
1902.....		35,340		48,504		13,488			
1903.....		57,100		60,745		32,246			
1904.....		43,649		107,396		15,502			
1905.....		103,442		61,852		62,586			
1906.....		46,516		97,762		109,883			
1907.....		33,900		73,200		81,517	\$224,356		
1908.....		42,445		112,829		109,429	22,234		
1909.....		42,358		178,318		56,841	32,594		
1910.....		34,998		178,318		91,915	25,845		
1911.....	91,713		306,385		341,027	100,149	65,141	\$508,044	
1912.....	54,327		185,423		285,941	186,046	36,944		
1913.....	116,000		292,616		1,202,817	137,812	38,215	320,961	
1914.....	38,000		362,209		1,604,240	494,495	69,477	289,087	
Total.....		\$596,126		\$1,413,186		\$2,087,633	\$584,453		

\*Concealed—Included in total.

NON-METALLIC MINERALS.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1914.—Concluded.

Year.	To carbonic acid plants. Value.	To paper mills. Value.	Fertilizer.		Other purposes.	To lime burners.	Rank of state. Value.	Total. Value.
			Tons.	Value.				
1899.....					\$2,375	\$157,657	.....12	\$281,769
1900.....					124,220	65,000	.....12	330,847
1901.....					101,399	136,173	.....12	429,771
1902.....					68,164	198,000	.....13	413,148
1903.....					4,747	132,600	.....14	390,473
1904.....					5,323	180,683	.....10	501,708
1905.....					142,790	9,380	.....12	544,754
1906.....					.....	.....	.....10	656,269
1907.....					278,287	.....	.....11	760,333
1908.....					253,990	.....	.....9	669,017
1909.....					327,571	.....	.....11	750,589
1910.....					299,305	.....	.....9	842,126
1911.....					.....	\$3,003	.....8	1,005,751
1912.....		\$12,558			440,857	3,447	.....8	1,139,560
1913.....		8,150			13,596	10,723	.....8	1,408,703
1914.....		10,723			395,874	7,048	.....7	1,457,981
.....		8,307	10,907	11,104	39,523	.....	.....	.....
Total.....		\$39,738		\$24,602	\$2,498,031			\$11,582,779



## LIME.

In the last ten years the lime industry in Michigan has made very little growth in comparison with the limestone industry. This is due largely to several causes, viz.: (1) the growing scarcity of cheap wood fuel for burning lime, (2) the substitution of concrete for stone and lime mortar in construction work, (3) the rapidly growing use of gypsum wall plaster and plaster substitutes, and (4) the unfavorable location of suitable limestone deposits. Formerly, owing to the abundance of wood fuel, lime was burned at many localities in the state, but now lime is produced only at Menominee, Manistique, Marblehead, and Rexton in the Northern Peninsula, and at Alpena, Afton, Petoskey, Bay Shore, and Charlevoix, and near Omer, and no lime is burned in the southern half of the Southern Peninsula. Most of the limestone deposits are in the northern part of the state relatively distant from large markets and the consequent high transportation charges make it difficult for Michigan burners to compete with lime producers in Indiana, Ohio, and Illinois, situated near cheap coal fuel supplies.

Concrete mortar owing to the ease and rapidity with which it can be handled has largely replaced stone and sand-lime mortar in construction work, and gypsum plasters and plaster board similarly have replaced sand-lime mortar for plastering.

Most of the lime produced is of the "hot" variety, but considerable mild magnesian lime is burned at Manistique, Marblehead, Petoskey, and Bay Shore. Hydrated lime is produced at Manistique and Charlevoix.

The total lime burned in 1914 was 66,507 tons valued at \$287,648 as compared with 77,088 tons valued at \$331,852 in 1913. This represents a decrease in amount of 10,851 tons and in value of \$44,204, or a loss of 13.7 per cent in amount and 13.3 per cent in value. The average price per ton was \$4.33 as against \$4.05 in 1913.

## PRODUCTION AND VALUE OF LIME IN MICHIGAN, 1904-1914.

Year.	Total lime burned.		Average price per ton.	No. of plants operating.	Rank of state. Production.
	Quantity. tons.	Value.			
1904.....	63,601	\$256,955	\$4 04		
1905.....	48,089	192,844	4 01		
1906.....	68,133	281,465	4 13	13	
1907.....	65,822	276,534	4 20	12	16
1908.....	68,050	282,023	4 14	10	15
1909.....	83,108	354,135	4 26	12	13
1910.....	72,345	303,377	4 19	10	14
1911.....	80,709	352,608	4 37	14	14
1912.....	74,720	311,448	4 17	11	16
1913.....	77,088	331,852	4 05	10	14
1914.....	66,507	287,648	4 33	10	14
Total.....	768,172	\$3,230,889			

## SANDSTONE.

The value of the annual output of sandstone in Michigan has decreased from \$188,073 in 1902 to only \$12,983 in 1911. In 1912 and 1913 there were slight increases, the total value of the output in each of these years was \$16,438 and \$19,224 respectively. In 1914 the industry almost ceased to exist, there being but one operator.

The decline of the sandstone industry in Michigan may be ascribed (1) to the poor quality of much of the sandstone, (2) to the substitution of concrete in construction work and, (3) to the greater use of brick and artificial stone.

Quarries were formerly operated in Coal Measure sandstones near Ionia and Grand Ledge and at many places in the Marshall sandstone in Calhoun, Hillsdale, Jackson, and Huron counties. Most of the sandstone in these formations, upon exposure to the weather for a few years, alters uniformly or in spots to an unsightly yellow color. The sandstone near Ionia, however, though soft and friable is streaked and mottled with red, orange, and yellow and makes a pleasing appearance in buildings. No quarries are now operating in sandstone of the Coal Measures or the Upper Marshall, but some rubble and riprap are produced in connection with the quarrying of grindstone from the Lower Marshall in Huron County.

All of the output of sandstone for 1914 was derived from the Jacobsville sandstone, apparently the local equivalent of the Lake Superior or Upper Cambrian sandstone. Extensive quarrying operations have been carried on for a number of years near Jacobsville but the Portage Entry Redstone Co. is now the only active operator. The "redstone"

or "brownstone" of the Jacobsville is well cemented, permanent in color and pleasing in appearance, but the great distance of the deposits from large markets has been and will continue to be a serious obstacle in the way of their development.

Formerly much sandstone was quarried for foundations but now concrete has largely replaced block stone for such purposes on account of the cheapness of concrete materials and the rapidity and ease with which concrete can be handled. Front and fancy brick, owing to their cheapness and to the artistic effects which can be obtained by their use, have largely supplanted stone as a building material, and apparently the sandstone industry in Michigan except the quarrying of grindstones will not again attain its former importance.

NON-METALLIC MINERALS.

\*PRODUCTION AND VALUE OF SANDSTONE IN MICHIGAN, 1899-1914.

Year.	Rough building. Value.	Dressed building. Value.	Curbing. Value.	Flagging. Value.	Rubble. Value.	Riprap. Value.	Crushed stone.		Other. Value.	Total. Value.
							Road making. Value.	Concrete. Value.		
1899	\$102,447	\$51,662	\$109	a					\$23,800	\$178,038
1900	73,850	58,800			\$26,519	b			19,000	182,650
1901	128,909				27,323	\$800				174,428
1902	136,280	23,600			10,365					188,073
1903	89,931	14,818			15,554					121,350
1904	47,593	36,035			10,657					74,868
1905	64,056	35,272			10,332					123,123
1906	35,272	18,950			10,403	770			12,700	65,365
1907	33,561	10,918		\$528	7,900	96				53,003
1908	15,100	18,813			5,190					39,103
1909	12,985	16,805			6,294					36,084
1910	13,312	15,416			2,505					31,233
1911	5,662	2,809			3,068	1,140			286	12,965
1912	c	c			c	c			c	16,438
1913	c	c			c	3,127			c	19,224
1914	c	c			c	d			c	
Totals			\$109						\$3,850	

a Included under curbing.

b Included under rubble.

c Included in total.

d Figures not given—only one operator.

\* Exclusive of sandstone made into grindstones and scythestones.

## TRAP ROCK.

Almost inexhaustible resources of trap rock occur in the western half of the Northern Peninsula, chiefly in the iron and copper bearing regions, but trap rock is quarried on an extensive scale only in the vicinity of Marquette. Large quantities of amygdaloid trap rock, however, are taken out in connection with copper mining in the Keweenaw peninsula. The trap rock from Marquette county is harder, tougher, and much less altered than the amygdaloid trap of the Copper Range. The inferior wearing qualities of the latter for road purposes, however, are partly compensated for by most superior cementing powers.

Most of the product is crushed for road making and concrete. On account of its hardness, toughness, and high cementing power trap rock is unexcelled as a road material. The great distance from markets with the consequent high transportation charges and the high cost of quarrying prevents the extensive development of the trap rock resources for concrete and road making in competition with the more easily accessible and cheaply obtained materials—limestone and gravel.

In 1914 the trap rock industry in Michigan suffered from the general depression in trade conditions and as a result there was a large decrease, the total value falling from \$92,201 in 1913 to only \$34,406 in 1914—a little more than one-third that of the year preceding. The decreases, however, were in crushed trap for concrete and in riprap, while there were slight increases in both the amount and value of crushed stone for road making. A new quarry was opened in the vicinity of Negaunee and the rock is reported to be gabbro rather than trap.

PRODUCTION AND VALUE OF TRAP ROCK IN MICHIGAN, 1911-1914.

Year.	No. of producers.	Crushed stone.				Riprap. Value.	Total. Value.	Rank. Value.
		Road making.		Concrete.				
		Quantity.	Value.	Quantity.	Value.			
		Tons.		Tons.				
1911.....	3			45,250	\$38,420		\$51,000	8
1912.....	5	21,805	\$18,366	11,355	9,340	\$8,500	36,206	8
1913.....	5	24,920	23,360	*	*	*	92,201	10
1914.....		25,690	24,863	4,448	4,771		34,406	
Total.....		72,415	\$66,598				\$213,813	

\*Included in total.

## GRINDSTONES AND SCYTHESTONES.

Although Michigan ranks second to Ohio in the production of grindstones and scythestones, the production of the latter state is five or six times that of Michigan. The "grit or grindstone" occurs in the lower part of the Marshall formation in Huron county. The Wallace Company of Port Austin and the Cleveland Stone Company operate quarries at Eagle Mills and Grindstone City respectively, where the gritstone occurs in low-lying and thinly drift covered ledges near the shore of Lake Huron. The surface deposits are removed by stripping and channeling machines cut the stone into square blocks eight feet or more in thickness. These are split with wedges along the bedding planes into thinner slabs which are loaded on cars by derricks, then taken to the mills.

The grindstones produced vary in size from very small ones up to those seven feet in diameter with a 14 inch face. The broken stone is worked up into scythestones.

As there are but two producers no tables of production and value can be given.

## SAND AND GRAVEL.

Owing to the general use of sand and gravel in the building trades, no other industry reflects general business conditions better than that of sand and gravel. As a consequence of the general industrial depression prevailing throughout the country during 1914 there was a large falling off in the output of sand and gravel particularly in building sand, and gravel for concrete. The total production in 1914 was 3,757,979 tons as compared with 6,422,818 tons in 1913, a net decrease of 2,664,839 tons or nearly 42 per cent. The decline in total value, however, was relatively less, the value falling from \$1,528,892 in 1913 to \$1,143,771 in 1914, a decrease of \$385,121, or about 25 per cent. In 1914 the production of building sand in Michigan was 1,088,650 tons valued at \$360,152. This represents a decrease in amount of 237,466 tons and in value \$55,585. In 1914, 2,140,359 tons of gravel valued at \$530,338 were produced as against 3,928,874 tons valued at \$915,205 in 1913. This represents a decrease in amount of 1,788,515 tons or about 45.5 per cent and in value of \$384,867 or over 42 per cent.

Michigan has enormous sand and gravel resources. The most important deposits occur in the form of ridges known as eskers or hogbacks, in irregular hills called kames, in outwash plains and deltas and in old beach ridges, features resulting from the last or Wisconsin glacial invasion.

Only a small portion of the sand and gravel resources have been developed and the chief developments are in the vicinity of cities,

in river channels and along the lake shores where means of transportation are favorable. The localities and counties in order of importance in production are Detroit and St. Clair rivers, Jackson, Macomb, Kent, Oakland, Ingham, Manistee, Livingston, Washtenaw, Ottawa and Lenawee counties, and the shores of Lake Michigan and Lake Huron.

PRODUCTION AND VALUE OF SAND AND GRAVEL IN MICHIGAN, 1904-1914.

Year.	Glass sand.		Molding sand.		Building sand.		Fire sand.		Engine sand.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.		Tons.	
1904			167,147	\$76,299	69,656	\$30,898				
1905			19,382	13,247	263,315	148,065	5,000	\$2,500		
1906	600	\$3,000	61,387	26,108	403,199	127,937			4,000	\$400
1907	4,300	8,600	54,172	24,190	451,646	157,150	6,000	3,000	1,534	153
1908	17,000	34,000	4,584	2,882	474,238	225,395			1,991	319
1909	65,000	79,000	53,226	20,756	1,090,419	327,247	4,000	2,000	12,415	1,493
1910	16,212	25,675	93,812	24,004	1,151,588	334,336	5,000	3,000	22,270	2,172
1911	*	*	68,878	17,901	833,729	247,997	*	*	25,392	4,447
1912	*	*	152,433	40,145	902,556	294,115			18,575	4,774
1913	*	*	50,763	17,493	1,326,016	415,737	4,542	4,524	4,447	647
1914	26,035	32,593	53,400	36,583	1,088,650	360,152			6,357	1,066
Totals			779,185	299,618	8,055,012	2,672,029			96,981	15,471

Year.	Furnace sand.		Paving sand.		Other sand.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.	
1904						
1905					50,187	\$14,476
1906	5,000	\$2,500			51,005	12,140
1907	3,858	3,133			173,724	12,187
1908	3,329	3,828			29,187	6,850
1909	3,183	3,660			295,612	50,953
1910	3,185	4,924			372,880	57,385
1911	*	*	152,144	\$29,650	114,801	52,005
1912			68,453	16,898	130,624	54,746
1913	†	†	533,261	108,328	113,318	20,342
1914	†	†	320,322	74,866	115,291	107,392
Totals			1,074,180	\$229,742	1,446,629	\$388,476

Year.	Railroad ballast.		Gravel.		Total.		Rank.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.	
1904					236,803	\$107,197		
1905			76,625	\$32,321	414,509	210,609	10	11
1906			72,598	25,614	597,789	197,699	12	13
1907			329,407	81,182	1,024,641	239,595	10	11
1908			312,262	94,081	842,591	370,365	8	9
1909			695,902	200,523	2,219,757	685,632	8	8
1910			1,197,791	364,841	2,862,738	816,337	7	8
1911			935,072	203,218	2,185,165	565,969	9	10
1912			1,409,180	407,925	2,681,821	818,603	9	8
1913			3,928,874	915,205	6,422,818	1,528,892	4	5
1914	7,565	\$781	2,140,359	530,338	3,757,979	1,143,771	8	7
Total	7,565	\$781	11,098,070	\$2,855,248	23,246,611	\$6,734,669		

\*Included under other sand.

†Included under fire sand.



## SALT.

The amount and value of salt produced in Michigan in 1914 were greater than in any previous year. The total quantity of salt in 1914 was 11,670,976 barrels, or 142,176 barrels more than in 1913. The total value was \$3,299,005, which represents a gain of only \$5,973. The small gain was due to slightly lower prices, the general average price per barrel being \$0.283 per barrel as compared with \$0.285 in 1913. During the period from 1905 to the present the average price has risen from \$0.196 to \$0.283 per barrel.

From 1880 to 1892 inclusive Michigan held first rank in the amount of salt produced. In 1893 New York assumed the lead and held it continuously with the exception of 1901 until 1905 when Michigan regained the leadership. Excepting the years of 1910 and 1911, Michigan has since held first place as a salt producer with New York as a close second.

Thirty years ago the center of the salt industry was in Saginaw Valley, chiefly along Saginaw River from Saginaw to Bay City. The industry was carried on in connection with the lumber mills and waste steam and fuel from the mills were utilized by more than a hundred lumber concerns in evaporating natural brines obtained from the Upper Marshall sandstone at depths varying from about 600 feet in Saginaw to nearly 1,000 feet in Bay City. With the decline of the lumber industry in Saginaw Valley the salt industry has become unimportant, there being but eight producers in 1914, one in Bay City and seven in Saginaw. Less than three per cent of the total output of salt in the state for 1913 and only 3.6 per cent for 1914 was produced in this district.

The chief salt producing districts are along the Detroit-St. Clair Rivers and at Ludington and Manistee. In these districts artificial brines are used for the manufacture of salt. The brine is obtained by forcing water through casings down to rock salt beds and then back to the surface. Rock salt is also mined. Over 96 per cent of the state output of salt for 1913 and 1914 came from these two districts.

The salt industry in Wayne county has made a most remarkable growth. Salt was first produced in this country in 1895, the output for that year being 13,077 barrels. In 1906 the production exceeded 1,000,000 barrels and in 1914 it was 6,593,816 barrels. Much of the salt produced in Wayne county is in the form of brine which is used in the manufacture of soda ash, bleach, caustic, etc. The Solvay Process Co. at Delray, the Michigan Alkali Co. at Ford City and Wyandotte, and the Pennsylvania Salt Co. of Wyandotte use great quantities of brine in the manufacture of such products.

In St. Clair county the chief salt producing centers are Port Huron, St. Clair and Marine City. The output of St. Clair county in 1914 was only 19 per cent of the state output, yet the value was 42.88 per cent of the total value for the state. The exceptionally high value of the product from this county is due to the fact that much of the salt produced is of the better grades, 59.2 per cent being table and dairy salt.

Rock salt is mined at Oakwood, a small suburb on the western side of Detroit by the Detroit Rock Salt Co. A drill hole at the shaft showed the presence of salt aggregating more than 450 feet in thickness, but present mining operations are in a 20 foot bed at the depth of 1,040 feet. A large part of the product is shipped to Chicago and St. Louis, and other large cities, where it is used chiefly in curing fish, meats, and hides, and in the manufacture of ice cream and for general refrigeration.

In the Manistee-Ludington district salt is made at Manistee, Filer City, and East Lake, all situated on Manistee Lake, Manistee county; and at Ludington, Mason county. In this district the salt industry is still largely carried on in connection with the lumber industry, utilizing waste steam and waste fuel for evaporating artificial brines. This district produced 2,420,334 barrels of salt or 20.82 per cent of the state output. Nearly all of the product is packer's salt, i. e., common fine and common coarse, only one company manufacturing table and dairy salt.

Bromine and bromides are produced from the natural brines of the Marshall sandstone at Midland and Mt. Pleasant, and calcium chloride at Mt. Pleasant and Saginaw.

The rock salt occurs in the Salina formation of Silurian age. There are three known rock salt areas, one in southeastern Michigan, a second in Alpena and Presque Isle counties, and a third in Mason and Manistee counties. South of the line from Muskegon through Kalamazoo to Trenton, Wayne county, no rock salt has been found, though wells have penetrated completely through the rock salt bearing formation at many places. The area of rock salt in southeastern Michigan as far as known extends from Trenton, Wayne county, northeast along Detroit and St. Clair rivers into western Ontario. The total area known to be underlain by rock salt in southeastern Michigan and western Ontario is several thousand square miles. The rock salt area extends northwest from Detroit River to Romulus and Dearborn in Wayne county, and Royal Oak in Oakland county but how far the salt area continues in this direction is unknown since there are no wells to the northwest of these places deep enough to reach the salt horizons. It is significant, however, that the aggregate thickness of the salt beds

at Royal Oak and Dearborn is greater than to the southeast along Detroit River. In southeastern Michigan the salt beds are very numerous and some of them very thick. There is an upper, thick, and apparently persistent bed from 60 to 125 feet in thickness and a lower very thick and continuous one having a maximum thickness of over 350 feet. The average aggregate thickness of the salt beds along Detroit and St. Clair rivers is about 400 feet thick, but at Royal Oak and Dearborn 609 and 556 feet of salt respectively were penetrated and at the former place the bottom of the Salina apparently was not reached.

In Alpena and Presque Isle counties the salt area while undoubtedly very large is of unknown extent. Rock salt was struck at Onaway, Grand Lake, and Alpena in great force, and the greatest aggregate thickness of rock salt yet penetrated in Michigan and Ontario is at Onaway, Presque Isle county. A test hole drilled for oil at this place penetrated over 800 feet of rock salt in a distance of 1,200 feet, and the lowest bed was 225 feet in thickness. At Grand Lake over 300 feet of salt were penetrated in a deep well without reaching the bottom of the rock salt formation.

In the Ludington-Manistee district the salt beds are few and thin. In the vicinity of Manistee only one bed is known. This has a thickness of 20 to 30 feet. At Ludington, however, four beds respectively 20, 12, 7 and 5 feet in thickness have been penetrated.

The depth to the first salt bed in southeastern Michigan varies from a minimum of 730 feet at Detroit to 1,500 and 1,600 feet at Port Huron and St. Clair. In Alpena and Presque Isle counties the depth is about 1,270 feet at Alpena, 1,284 feet at Grand Lake, and 1,630 feet at Onaway.

The total area of the rock salt districts in Michigan is unknown, but it is undoubtedly several thousand square miles and present evidence, while not conclusive, indicates that the three known rock salt districts are but parts of one and the same great rock salt area.

PRODUCTION AND VALUE OF SALT IN MICHIGAN AND UNITED STATES,  
1860-1914.

Year.	U. S. production. Quantity, bbls.	Michigan production.		Per cent of total. Mich-igan.	Rank, quantity.	Michigan.	
		State Salt Inspectors.* Quantity, bbls.	U. S. G. S.† Quantity, bbls.			Value. Michigan.	Rank Value.
1860.		4,000					
1861.		125,000					
1862.		243,000					
1863.		466,000					
1864.		529,073					
1865.		477,200					
1866.		407,997				\$734,395	\$1.80
1867.		474,721				840,255	1.77
1868.		555,690				1,028,027	1.85
1869.		561,288				786,835	1.58
1870.		621,352				820,185	1.32
1871.		728,175				1,063,135	1.46
1872.		724,481				1,057,742	1.46
1873.		821,346				1,127,984	1.37
1874.		1,026,970				1,220,094	1.19
1875.		1,081,856				1,190,042	1.10
1876.		1,482,729				1,556,865	1.05
1877.		1,660,997				1,411,847	0.85
1878.		1,855,884				1,577,501	0.85
1879.		2,058,040				2,099,200	1.02
1880.	5,961,060	2,676,588	2,485,177	41.69	1	2,271,931	0.75
1881.	6,200,000	2,750,299		44.35	1	2,418,171	0.85
1882.	6,412,373	3,037,317	3,037,317	47.36	1	2,126,122	0.70
1883.	6,192,231	2,894,672	2,894,672	46.74	1	2,344,684	0.81
1884.	6,514,937	3,161,806	3,161,806	48.53	1	2,392,648	0.757
1885.	7,038,653	3,297,403	3,297,403	46.84	1	2,967,663	0.900
1886.	7,707,081	3,667,257	3,667,257	47.58	1	2,426,989	0.661
1887.	8,003,962	3,944,309	3,944,309	49.17	1	2,291,842	0.581
1888.	8,055,881	3,866,228	3,866,228	47.99	1	2,261,743	0.585
1889.	8,005,565	3,846,979	3,856,929	48.17	1	2,088,909	0.541
1890.	8,776,991	3,838,637	3,838,632	43.72	1	2,302,579	0.600
1891.	9,987,945	3,927,671	3,966,748	39.52	1	2,037,289	0.513
1892.	11,698,890	3,812,504	3,829,478	32.81	1	2,046,963	0.523
1893.	11,897,208	3,514,485	3,057,898	25.70	2	888,837	0.287
1894.	12,968,417	3,138,941	3,341,425	26.53	2	1,243,619	0.375
1895.	13,669,649	3,529,362	3,343,395	24.46	2	1,048,251	0.315
1896.	13,850,726	3,236,242	3,164,238	22.89	2	718,408	0.229
1897.	15,973,202	3,622,764	3,993,225	24.99	2	1,243,619	0.313
1898.	17,612,634	4,171,916	5,263,564	29.88	2	1,628,081	0.311
1899.	19,708,614	4,732,669	7,117,382	36.14	2	2,205,924	0.309
1900.	20,869,342	4,738,085	7,210,621	34.55	2	2,033,731	0.282
1901.	20,566,661	5,580,101	7,729,641	37.58	1	2,437,677	0.328
1902.	23,849,231	4,994,245	8,131,781	34.10	2	1,535,823	0.188
1903.	18,968,089	4,387,982	4,297,542	22.65	2	1,119,984	0.260
1904.	22,030,002	5,390,812	5,425,904	24.62	2	1,579,206	0.309
1905.	25,966,122	5,671,253	9,492,173	35.24	1	1,851,332	0.196
1906.	28,172,380	5,644,559	9,836,802	36.31	1	2,018,760	0.203
1907.	29,704,128	6,298,463	10,786,630	35.39	1	2,231,129	0.208
1908.	28,822,062	6,247,073	10,194,279	35.34	1	2,458,303	0.241
1909.	30,107,646	6,055,661	9,966,744	33.10	1	2,732,556	0.274
1910.	30,305,656	5,597,276	9,452,022	31.18	2	2,231,262	0.236
1911.	31,183,968		10,320,074	33.10	2	2,633,155	0.255
1912.	33,324,808		10,946,739	32.84	1	2,974,429	0.277
1913.	34,393,227		11,528,800	33.52	1	3,293,032	0.285
1914.	34,402,772		11,670,976	33.92	1	3,299,005	0.283
Totl.			209,217,812			\$89,897,763	

\*Office of State Salt Inspector abolished in 1911.

†In cooperation with the Michigan Geological Survey after 1909.

‡Includes production of Porto Rico.

## MINERAL RESOURCES OF MICHIGAN.

## PRODUCTION AND VALUE OF SALT IN MICHIGAN BY GRADES, 1906-1914.

Year.	Table and dairy.		Packers.			
	Quantity.	Value.	Common fine.		Common coarse.	
			Quantity.	Value.	Quantity.	Value.
	Barrels.		Barrels.		Barrels.	
1906	509,905	\$362,368	2,927,478	\$757,470	2,021,287	\$618,727
1907	657,509	392,641	3,601,270	914,154	1,743,840	471,378
1908	584,452	620,647	3,454,062	968,617	2,020,956	610,286
1909	585,370	732,907	3,530,303	1,125,095	2,103,719	647,878
1910	708,434	565,653	2,216,181	734,828	1,902,465	506,301
1911	817,486	742,702	2,362,075	698,203	2,070,745	745,720
1912	905,593	920,782	2,225,337	645,692	2,086,492	835,673
1913	1,028,000	1,037,402	2,704,936	852,135	2,259,164	896,521
1914	1,092,344	1,025,164	2,668,989	911,016	2,380,378	870,715

Year.	Packers.		Other, rock, etc.		Brine and other.*	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1906	91,098	\$33,733			4,387,043	\$246,462
1907	110,459	48,455			4,664,552	235,729
1908	134,726	53,669			3,901,083	205,084
1909	93,357	3,983			3,648,395	185,051
1910	92,426	43,942			4,104,934	211,317
1911	105,401	45,421	576,595	\$181,865	4,387,772	219,244
1912	223,866	84,638	763,908	250,680	4,737,038	236,852
1913	50,557	25,371	727,364	244,172	4,756,779	237,431
1914	†	†	712,530	252,024	4,816,735	240,086

Total.		
Year.	Value.	
Quantity.	Value.	
	Barrels.	
1906	9,936,802	\$2,018,760
1907	10,786,630	2,062,357
1908	10,194,270	2,458,303
1909	9,966,744	2,732,556
1910	9,452,022	2,231,262
1911	10,320,074	2,633,155
1912	10,946,739	2,974,429
1913	11,528,800	3,293,032
1914	11,670,976	3,299,005

\*Brine only after 1910.

†See common fine and common coarse after 1913.

PRODUCTION AND VALUE OF SALT IN MICHIGAN BY COUNTIES IN 1914.

County.	Table and dairy.		Packers.			
	Barrels.	Value.	Common fine.		Common coarse.	
			Barrels.	Value.	Barrels.	Value.
Bay.....	*	*	1,026,419	\$277,191	200,328	\$82,852
Isabella.....						
Mason.....						
Midland.....						
Manistee.....			*	*	*	*
Saginaw.....			360,633	175,302	30,795	15,065
St. Clair.....	837,559	\$884,112	687,683	267,402	671,979	257,181
Wayne.....	204,647	114,729	342,613	61,516	606,800	183,669
<b>Total barrels...</b>	<b>1,092,344</b>	<b>\$1,025,164</b>	<b>2,668,989</b>	<b>\$911,016</b>	<b>2,380,378</b>	<b>\$870,715</b>
<b>Tons.....</b>	<b>152,928</b>		<b>373,659</b>		<b>333,253</b>	

County.	Other grades.		Rock salt.		Brine.	
	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.
Bay.....	*	*			*	*
Isabella.....						
Mason.....						
Midland.....						
Manistee.....	*	*			*	*
Saginaw.....	*	*			*	*
St. Clair.....	*	*	*	*	*	*
Wayne.....	*	*	*	*	*	*
<b>Total barrels...</b>	<b>34,180</b>	<b>\$9,038</b>	<b>*</b>	<b>*</b>	<b>4,816,735</b>	<b>\$240,086</b>
<b>Tons.....</b>	<b>4,785</b>		<b>*</b>	<b>*</b>	<b>674,343</b>	

County.	Total.		Quantity, per cent.	Value, per cent.
	Barrels.	Value.		
Bay.....				
Isabella.....				
Mason.....				
Midland.....				
Manistee.....	1,040,634	422,346	8.92	12.80
Saginaw.....	398,067	191,068	3.40	5.79
St. Clair.....	2,216,842	1,414,668	19.00	42.88
Wayne.....	6,593,816	882,368	56.50	26.75
<b>Total barrels...</b>	<b>11,670,976</b>	<b>\$3,299,005</b>		
<b>Tons.....</b>	<b>1,633,937</b>			

\*Included in total.

## CEMENT.

## Growth of Industry.

In 1895 less than 1,000,000 barrels of Portland cement were manufactured in the United States, less than quarter of the present production of Michigan. At this date the rotary kiln, burning powdered coal, was successfully introduced and inaugurated the present era of concrete construction. From 1895 to 1907 the growth was phenomenal, nearly 48,000,000 barrels being produced in the latter year. The general financial depression in 1907 caused a temporary check, but the growth was resumed in 1908 and continued until 1913 when over 92,000,000 barrels were made. In 1914, however, there was a decrease of more than 3,865,000 barrels, owing to the unsettled business conditions largely engendered by the present European war.

In Michigan as early as 1878 a vertical kiln plant was erected near Kalamazoo for the manufacture of Portland cement from marl and clay but the enterprise was a failure on account of the high cost of production and the plant was abandoned in 1882. The Peerless Portland Cement Co. in 1896 erected a vertical kiln plant at Union City, Branch county, and began the successful manufacture of cement from marl and shale. In 1902, however, the old vertical kilns were replaced by modern rotary types. In 1897 the Bronson Portland Cement Co. erected a mill at Bronson, Branch county, and the next year the Coldwater Portland Cement Co., now the Wolverine Portland Cement Co., was formed, a plant being built at Coldwater and later another at Quincy, Branch county.

The "boom" years in Michigan were between 1899 and 1901, twenty companies being organized during this period for the manufacture of cement from marl. Some of the companies made very elaborate plans but never got beyond this stage; only ten ever reached the productive stage and but five of these are now in operation. In all, since 1896, 34 cement plants have been projected or built in Michigan, only eleven of which were in operation in 1914 and one, the Egyptian Portland Cement Co. at Fenton, Genesee county, was reorganized and the plant rebuilt in preparation for active operations in 1915.

## Raw Materials.

In Michigan the principal raw materials for the manufacture of Portland cement are marl and limestone, and clay and shale. Gypsum is also used but in relatively small amounts. Nearly all of the early companies organized planned to utilize marl and clay or shale, but the high cost of driving off the large amount of water contained in marl

has caused some of them to change to limestone. At present six of the companies are using marl and clay, and four limestone and shale or clay. According to reports, the reorganized Egyptian Portland Cement Co. at Fenton will use marl and shale.

The following table shows that Michigan produced 4,285,345 barrels of Portland cement in 1914, as against 4,186,236 barrels in 1913. This represents an increase of over 99,109 barrels or 2.36 per cent as compared with an increase of 691,615 or 19.79 per cent in 1913. Shipments increased from 4,081,281 barrels in 1913 to 4,218,429 barrels in 1914, a gain of 137,148 barrels or 3.36 per cent. In both production and shipments the totals were the largest in the history of the industry in Michigan. Owing to lower average prices, however, the value of cement sold decreased from \$4,228,879 in 1913 to \$4,064,781 in 1914, a loss of \$164,098 or 3.88 per cent.

Of the total shipments 2,970,524 barrels were sold in Michigan and 1,314,821 barrels in other states and in Ontario. Of the extra-state shipments 368,722 barrels were shipped to Ohio, 293,923 barrels to Indiana, 273,225 barrels to Minnesota, 235,012 to Wisconsin, 134,588 to Illinois, and the remainder to Kentucky and Ontario.

During the latter part of 1912 and throughout 1913, cement operators enjoyed the highest prices since 1907. This accounts for the great increases in production, shipments, and total value in 1913. In 1914, however, prices were on the average considerably less though the demand was reported nearly equal to that in 1913. The average price per barrel fell from \$1.036 in 1913 to \$0.964 in 1914, a loss of \$0.072 per barrel.



## PRODUCTION, VALUE, ETC., OF PORTLAND CEMENT IN MICHIGAN AND UNITED STATES, 1896-1914.

Year.	No. of plants in operation.	Michigan Rank.	No. of kilns.	Rotary.	Daily capacity, Bbls.	Michigan, Cement made, Bbls.	U. S. Cement made, Bbls.	Michigan, per cent made.	*Change per cent cement made.	Michigan, Cement shipped, Bbls.	Michigan, Cement Value.	U. S. Cement shipped, Value.	Michigan, per cent of value.	Michigan, stock on hand, Dec. 31, Bbls.	Michigan, average price per barrel.	U. S. average price per barrel.
1896	1					4,000	1,543,023	0.25	275.0		\$7,000	\$2,424,011	0.29		\$1.75	\$1.57
1897	2					17,000	3,677,773	0.56	215.0		26,250	4,315,891	0.6		1.75	1.81
1898	2					77,000	5,692,284	2.11	313.3		132,750	5,070,773	2.8		1.747	1.92
1899	4	4				343,566	5,652,266	6.1	348.2		513,849	8,074,371	6.36		1.482	1.43
1900	6	2				664,750	8,482,020	7.8	93.4		830,990	9,280,325	8.9		1.25	1.09
1901	10	3				1,025,718	12,711,225	8.0	54.1		1,128,900	12,532,360	9.0		1.10	0.99
1902	10	3				1,377,006	17,230,644	8.1	55.7		2,124,298	27,804,978	10.2		1.363	1.21
1903	13	3				1,955,183	22,342,973	8.7	23.9		2,574,780	27,713,318	9.7		1.367	1.24
1904	16	4				2,287,160	26,505,861	8.5	14.9		2,865,656	33,355,119	10.1		1.052	0.88
1905	16	5				2,773,283	35,246,812	7.9	23.4		2,921,507	33,245,867	8.7		1.053	0.94
1906	14	4				3,747,525	46,463,424	8.06	35.5		4,814,965	52,466,186	9.2		1.284	1.13
1907	14	4				3,572,668	48,785,390	7.3	-4.6		4,384,731	53,992,551	8.1		1.287	1.11
1908	15	7				2,892,576	51,072,612	5.6	-19.0		2,556,215	43,047,679	5.8		0.863	0.85
1909	12	7				3,212,751	64,991,431	4.9	11.6		2,619,259	52,858,354	4.9		0.816	0.813
1910	12	8				3,687,719	76,549,951	4.8	11.7		3,378,940	68,205,800	4.9		0.916	0.891
1911	11	8	96	22,400		3,686,716	78,528,637	4.69	-0.03		3,024,676	66,248,817	4.56	508,758	0.82	0.843
1912	11	8	92	19,450		3,494,621	82,438,096	4.23	-5.21	3,651,084	3,145,001	69,109,800	4.55	370,956	0.861	0.813
1913	11	8	83	19,900		4,186,236	92,067,131	4.21	19.79	4,081,251	4,228,879	88,689,377	4.77	473,563	1.086	1.005
1914	11	7	77	19,100		4,285,345	88,230,170	4.85	2.37	4,218,459	4,064,781	86,437,956	4.70	538,846	0.964	0.927

\*Minus sign indicates decrease.

## GYPSUM DEPOSITS IN MICHIGAN.

## OCCURRENCE AND DEVELOPMENT.

Gypsum in Michigan occurs chiefly in the Michigan Series or Lower Grand Rapids of the Mississippian and in the Lower Monroe and the Salina of the Silurian. The Grand Rapids group immediately underlies the interior coal basin and outcrops at many places in a nearly continuous belt around it. On the southeastern side of the coal basin, the gypsum bearing series is absent or present only locally, either having been removed by erosion or never deposited. The Monroe formation outcrops only in the extreme southeastern portion of the state and in the St. Ignace peninsula and adjacent islands. The Salina does not come to the surface in southern Michigan and has not been certainly differentiated from the Monroe formation in St. Ignace peninsula.

The gypsum deposits of Michigan are all of the massive rock variety. In the Michigan Series gypsum occurs in lenticular beds intercalated in shales and shaly limestones. The beds vary in thickness from a fraction of an inch up to 25 feet or more. Some, particularly the thinner ones are of very local extent, while some of the thicker ones have been traced over areas many square miles in extent. In some localities there are numerous beds of gypsum, in others none. Drillings, however, indicate that gypsum beds are generally present throughout much of the formation, but that within the limits of the coal basin they are largely replaced by anhydrite and are too deep to be of commercial importance at present.

The gypsum rock is generally very pure especially in the thicker beds and it is usually white to reddish in color.

In the Lower Monroe and the Salina of southeastern Michigan the gypsum is largely anhydrite, or anhydrous calcium sulphate and occurs in association with dolomite and rock salt beds. The beds are very numerous and some of them are very thick, thicknesses of over 50 feet having been reported. The areas in southern Michigan underlain by anhydrite apparently cover thousands of square miles but this mineral has no commercial value at present. Though the beds were gypsum instead of anhydrite, their generally great depth would render them of little value.

The deposits of gypsum have been developed in three areas, the Grand Rapids-Grandville in Kent county, the Alabaster in south-

eastern Iosco county, and the St. Ignace in Mackinac county, but operations ceased in the last district many years ago. Large but undeveloped deposits are known to occur in western Iosco county, southeastern Ogemaw, and southern Arenac county. Gypsum beds 5 to 30 feet in thickness are reported to occur at comparatively shallow depths at Ionia, Ionia county, and also in Saginaw county. Beds 6 to 12 feet thick were encountered in shallow wells at Bellevue and Eaton Rapids, in Eaton county. The wide spread occurrence of gypsum beds in the Michigan Series is indicated not only by the numerous deposits of gypsum near the margin of the formation but also by the striking of thick beds of gypsum within the limits of the Coal Basin in deep wells at Grayling, Gladwin, Bay City, Midland, Saginaw, Mt. Pleasant, Alma, and St. Johns. These beds are probably too deep for development under present conditions.

The Grand Rapids-Grandville gypsum area, as developed, extends in a belt three or four miles in width along the valley of Grand River from the northern part of Grand Rapids southwest through Grandville and into eastern Ottawa county, a distance of 10 miles or more. Although the productive area extends in a general northeast-southwest direction, the strike of the gypsum bearing rocks in Kent county is northwest-southeast. The valley of the Grand varies in width from one to one and one-fourth miles at Grand Rapids to three or four miles at Grandville, the bluffs along the valley being formed by drift material and rising 100 to 150 feet above the river flats. Exploration and development were naturally confined to the valley and its tributaries where the rock is covered by only a few feet of river silt or sand and gravel. Further exploration along creek valleys to the northwest and to the southeast along the strike of the formation will probably show that the gypsum beds have a much greater extent in these directions than now known. The known productive portion of the Grand Rapids-Grandville area is estimated at about 25 square miles. In the district there are several beds of gypsum of minable thickness, three of which, and probably five, have been developed on a commercial scale. At Grand Rapids, the first bed, six feet in thickness is quarried, the second, a twelve foot bed is both quarried and mined, and the third a 22 foot bed, about 60 feet below the second is mined. The upper bed is absent in many places, having been removed by erosion, and the second is locally very thin, or even entirely wanting, apparently from solution. When the twelve foot bed is mined the six foot bed is generally left for the roof of the mine. The 22-foot bed is divided near the middle by a shale parting one foot or less in thickness. Until a few years ago only the two upper beds at Grand Rapids were worked for it was supposed that water would be very troublesome in mining, but when

a shaft was sunk to this bed mining conditions were found to be ideal, the mine entries being perfectly dry.

At Grandville the upper bed is about 11 feet in thickness and is overlain by eight to ten feet or more of gravel and soil. This bed is quarried, the overburden being removed by stripping. The floor of the quarry consists of four feet of hard limestone which rests directly on the second bed of gypsum, 14 feet in thickness, which is mined. These two beds of gypsum may be the equivalent of the 22-foot "split" in west Grand Rapids, the four feet of limestone corresponding to the shale parting. More evidence, however, is needed before definite correlations are warranted.

North of the river near Grand Rapids the mines enter the bluffs at the level of the mills but down an incline. The mines are locally known as "caves." South of the river, near Plaster creek, the bottom of the lowest bed quarried is about ten feet above the river. At Grandville the quarries are about a mile south of the river and but little above it. From their slight elevation above the water the quarries on the river flats have much trouble from water and several quarries have been abandoned from this cause.

The overburden in the vicinity of the quarries varies from a few feet to more than 20 feet of sand and gravel. Near the Plaster creek quarries surface materials are relatively thin but there is 12 to 15 feet of shale above the six foot bed of gypsum. The heavy cost of removing the overburden and water has caused the gradual abandonment of quarries and the opening of mines.

The Alabaster quarry and mill are located in the southeastern part of Iosco county, six miles south and west of Tawas City, and three-fourths of a mile from the shore of Saginaw Bay. The bed of gypsum is from 18 to 23 feet in thickness, and near the Bay it was covered by five to eight feet of gravel, but farther west the overburden is a tough boulder clay 9 to 14 feet or more in thickness, which is removed by steam shovels. The base of the bed is about 15 feet above the level of the Bay. A large area has been worked out and the face which has been developed in the form of a horse shoe is nearly a mile in length. This is not only the largest quarry in the state but one of the largest in the United States.

The Alabaster bed is known to be of commercial thickness over an area of 25 to 30 square miles in southeastern Iosco county and northwestern Arenac county, but its surface exposure is of limited extent. The bed dips gently to the south-southwest, where it is buried under other strata. In the western part of Iosco county and southern Ogemaw county gypsum outcrops in numerous places or occurs at shallow depths. Drillings north and west of Alabaster show the

presence of at least five workable beds below the Alabaster bed, the thickness of the beds ranging from 4 to 22 feet.

In Arenac county in the vicinity of Turner and in the northeastern part of the county a persistent bed of gypsum 50 to 100 feet above the Alabaster bed has been discovered in wells. This is known as the Turner\* bed. There are two areas in the county in which this bed is thick enough for mining, one in the vicinity of Turner and the other in the northeastern part of the county. The combined area of the two territories is 20 to 25 square miles, but further exploration will probably increase the minable area of the Turner bed very greatly.

Gypsum occurs at various places in the St. Ignace peninsula† and on adjacent islands. In 1850 a quarry was opened near Pt. Aux Chenes seven miles west of St. Ignace. A dock was built and gypsum was shipped to mills in Chicago. Owing to various troubles, chief of which were water in the quarry and a scourge of smallpox, the quarry was operated more or less interruptedly for a number of years and finally, when an ice floe carried away the dock, the enterprise was abandoned. Nothing further was done until 1894 when test holes were put down two miles west of the old quarry. According to reports a ledge of gypsum a few feet in thickness was found under light cover and beds totalling 60 feet in aggregate thickness were penetrated by the borings. In a deep well two miles north of St. Ignace some gypsum was struck at 35 feet, 13 feet of gypsum at 174 feet and five feet at 255 feet. Drillings on a bench at the foot of Rabbit's Back Peak, a high limestone spur projecting into the lake four miles north of St. Ignace, showed some gypsum a few feet below the surface, a 21 foot bed at about 30 feet, and a nine foot bed at 57 feet. The surface of the land on which the drillings were made is only 10 to 15 feet above the lake. In some places gypsum was found under only about 14 inches of soil and near the extremity of Rabbit's Back Point a bed outcrops close to the water's edge and can be seen beneath the water near the shore. Gypsum is found on adjoining tracts of land and at Gross Point four miles farther north. From this point eastward outcrops of gypsum occur along the shore for several miles. On St. Martins Island directly east of Gross Point, gypsum is struck in shallow wells over a large part of the southern portion of the island and may be seen in the water along the shore. The top ledge, said to be three feet thick, is near the surface, and other beds occur lower down. According to analysis the rock is very pure, containing over 98 per cent of gypsum. Present evidence indicates the presence of seven easily accessible heavy beds of gypsum in St. Ignace peninsula and adjacent islands, but whether or not water

\*W. M. Gregory, Geological Rept. Arenac county, Pub. 11., Geol. Ser. 8, pp 54-55.

†G. P. Grimsley, Vol. IX, p. 83, Mich. Geol. Survey.

would be generally troublesome in quarrying or mining is uncertain.

According to Lane there are many signs of gypsum deposits in the northern part of the Beaver Island group in Lake Michigan.

#### HISTORY.\*

In 1827 gypsum was discovered on Plaster creek which flows into Grand River in the southwestern part of Grand Rapids and it was first calcined some years later by James Clark who used an old Indian corn mill for grinding the rock and a caldron kettle for calcining. The first mill was built on Plaster creek in 1841 near the crossing of the Grandville road. The machinery consisted of one run of millstones and a thick bottomed two-barrel caldron kettle. Most of the gypsum, however, was ground into land plaster, and 10 years later 60 tons were produced daily. In 1843 gypsum was discovered on the north side of Grand River and in 1849 a mill was built near the site of the present Eagle Mill No. 1 of the Grand Rapids Plaster Co. A second mill, now the Eagle Mill No. 2 of this company, was erected on neighboring property in 1869.

In the early 60's gypsum was discovered south of Grandville, six miles southwest of Grand Rapids, through the overturning of an old tree by high wind, and two mills were built, one in 1873 and the other in 1874. Other mills were built and quarries opened later at various times but owing to the keen competition and faulty methods of calcining many of the ventures were unsuccessful. About 1901 consolidation of the various interests began and at present the seven mines and quarries and eight mills in the Grand Rapids-Grandville district are owned or controlled by four companies.

Gypsum had been discovered by the Indian traders at Alabaster before 1841 but it was not until 1862 that a quarry was opened, supplying small mills at Winona and Bay City, Bay county, and Monroe, Monroe county, with gypsum for the manufacture of land plaster. Later a mill was built and at present this quarry, operated by the U. S. Gypsum Company, is one of the largest in the United States. Another quarry was opened in 1870 about three miles south of Alabaster but trouble with water caused its abandonment.

In 1823 Dr. J. J. Bigsby made the first discovery of gypsum in Michigan on St. Martins Island. In the 50's a gypsum quarry was opened near Pt. Aux Chenes seven miles west of St. Ignace, Mackinac county, and supplied mills at Chicago with gypsum. Water was very troublesome and after a few years, when an ice gorge carried away the dock the quarry was abandoned and no attempt has been made to reopen the quarry since.

\*Vol. IX, Pt. II. The Gypsum of Michigan by G. P. Grimsley. Mich. Geol. Surv.

## PRODUCTION.

From 1860 to 1890 inclusive the annual production of gypsum in Michigan never reached 75,000 tons. In 1891 the production increased to nearly 98,000 tons and the next year reached 139,557 tons. The industry suffered severely from the general financial depression in the country in 1892-1893 and three years later, in 1895, the production had decreased to only 66,519 tons or less than half the production of 1892. By 1899 the industry had recovered from the effects of the depression and entered a period of growth and development which continued almost without interruption up to the close of 1913. In 1913 the total quantity of gypsum mined was 423,896 tons, the largest in the history of the industry, but, in 1914, owing to the industrial depression prevailing throughout the United States, there was a marked decrease, the production falling to 393,006 tons, or about 30,000 tons less than in the previous year. The value of gypsum products in 1914, however, was \$705,841 or only \$15,484 less than in 1913.

From 1868 to 1887 more than half of the gypsum output was ground and sold as land plaster. Since 1887 the grinding of land plaster has become relatively of less and less importance, the production in 1913 and 1914 being respectively only 9,604 and 9,322 tons. The rapid and steady growth of the gypsum industry since 1898 is due largely to the invention of various mixed gypsum wall plasters, plaster board and calcimines and to the increased use of gypsum in the manufacture of Portland cement. The mining and quarrying operations of the gypsum industry have become relatively unimportant in comparison with the manufacturing of gypsum products.

NON-METALLIC MINERALS.

PRODUCTION OF GYPSUM IN MICHIGAN, 1868-1914.

Year.	Ground into land plaster. Tons.	Gypsum calcined into plaster. Tons.	Sold crude. Tons.	Total production. Tons.	Total value.	Rank.	
						Quantity.	Value.
Before 1868..	132,043	14,285		146,328	\$671,022		
1868.....	28,837	6,244		35,081	165,298		
1869.....	29,996	7,355		37,351	178,824		
1870.....	31,437	8,246		39,683	191,718		
1871.....	41,126	8,694		49,820	234,054		
1872.....	43,536	10,673		54,209	259,524		
1873.....	44,972	14,724		59,696	297,678		
1874.....	39,126	14,723		53,849	274,284		
1875.....	27,019	10,914		37,933	195,386		
1876.....	39,131	11,498		50,629	248,504		
1877.....	40,000	9,819		49,819	238,550		
1878.....	40,000	8,634		48,634	229,070		
1879.....	43,658	9,070		52,728	247,192		
1880.....	49,570	18,929		68,499	349,710		
1881.....	33,178	20,145		53,323	293,872		
1882.....	37,821	24,136		61,957	344,374		
1883.....	40,082	28,410		68,492	377,567		
1884.....	27,888	27,959		55,847	335,382		
1885.....	28,184	25,281		53,465	286,802		
1886.....	29,373	27,370		56,748	308,094		
1887.....	28,794	30,376		59,170	329,392		
1888.....	22,177	35,125		57,302	347,531		
1889.....	19,823	36,800		56,623	353,869		
1890.....	12,714	47,163	15,000	74,877	192,099		
1891.....	15,100	53,600	11,000	97,700	223,725		
1892.....	14,458	77,599	47,500	139,557	306,527		
1893.....	16,263	77,327	31,000	124,590	303,921		
1894.....	11,982	47,976	20,000	79,958	189,620		
1895.....	9,003	51,028	6,488	66,519	174,007		
1896.....	6,582	60,352	700	67,634	146,424		
1897.....	7,193	71,680	16,001	94,874	193,576		
1898.....	13,345	77,852	1,984	93,181	204,310		
1899.....	17,196	88,315	39,266	144,776	283,537		
1900.....	10,354	86,972	33,328	129,654	285,119	2	2
1901.....	9,808	129,256	46,086	185,150	267,243	1	1
1902.....	13,022	158,320	68,885	240,227	459,621	1	1
1903.....	18,409	198,119	52,565	269,093	700,912	1	1
1904.....	18,294	185,422	34,669	238,385	541,197	1	1
1905.....	20,285	203,313	24,284	247,882	634,434	1	2
1906.....	30,220	208,715	27,517	341,716	753,878	1	2
1907.....	15,500	197,666	36,543	317,261	681,351	3	3
1908.....	11,414	192,403	40,324	327,810	491,928	1	3
1909.....	11,890	344,171	45,781	394,907	1,213,347	2	1
1910.....	7,097	240,905	64,566	357,174	667,199	2	2
1911.....	15,548	206,299	79,050	347,296	523,926	3	4
1912.....	10,103	243,656	63,819	384,297	621,547	2	3
1913.....	9,604	278,368	60,706	423,896	721,325	3	3
1914.....	9,322	249,648	61,227	393,006	705,841	3	3
Totals..	1,232,477	4,185,635	928,289	6,894,576	\$18,244,311		



## MINERAL RESOURCES OF MICHIGAN.

## PRODUCTION OF GYPSUM IN MICHIGAN, 1911-1914.

Year.	Gypsum sold crude.											
	Crude gypsum mined.		To Portland cement mills.		As land plaster.		For other purposes.		Total sold crude			
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
	Tons.		Tons.		Tons.		Tons.		Tons.		Tons.	
1911.....	347,296	\$69,497	63,489	\$15,706	15,548	\$52	13	\$52	79,050	\$85,255	79,050	
1912.....	364,297	52,420	53,711	9,375	10,103	5	5	50	63,819	61,845	63,819	
1913.....	423,896	*	*	10,222	9,604	*	10,320	9,011	60,706	55,969	60,706	
1914.....	393,006	*	*	10,761	9,322	*	*	*	61,227	51,242	61,227	

Year.	Gypsum sold calcined.											
	As mixed wall plaster.		As plaster of Paris, etc.		As stucco.		As dental plaster.		To plate glass works.			
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
	Tons.		Tons.		Tons.		Tons.		Tons.		Tons.	
1911.....	146,920	\$381,362	47,989	\$88,168	82,010	\$168,734	20	\$110	11,370	\$19,031	11,370	
1912.....	146,099	368,676	937	3,229	95,402	292,675	3	12	6,214	8,078	6,214	
1913.....	166,711	437,720	*	*	83,780	173,172	*	*	*	*	*	
1914.....	163,972	475,638	*	*	*	*	*	*	*	*	*	

\*Included in total.

NON-METALLIC MINERALS.

PRODUCTION OF GYPSUM IN MICHIGAN, 1911-1914.—Concluded.

Year.	Gypsum sold calcined.				Total value.	Kettles in mill.		Daily capacity of mill.	Shifts run by mills during year.		No. mines and quarries.	No. mills.	
	For other purposes.		Total sold calcined.			No.	Size.		24 hrs.	Total No.			Hrs. in shift.
	Quantity.	Value.	Quantity.	Value.									
	Tons.		Tons.				Tons.						
1911.....	8,393	\$10,973	206,299	\$488,671	29	8 x 10	2,200 +			8	8		
1912.....	9,897	15,850	243,656	559,702	28	8 x 10	2,140	1,850	11	9	8		
1913.....	1,811	5,433	278,368	685,356	28	8 x 10	1,785	1,368	11	7	8		
1914.....			249,648	654,599	28	8 x 10	1,860	2,043	11	8	8		

## CLAY.

The clays of Michigan are of three general classes, viz., (1) morainic or drift clays (2) lake clays and (3) river silts. Deposits of kaolin or china clays are unknown in Michigan and the chances for the occurrence of commercial deposits of such clays appear to be small. Deposits of kaolin have been reported at various places in the Northern Peninsula, but these as far as investigated proved to be white highly calcareous lake clays of the slip variety. The morainic clays—boulder and till clays, are always calcareous, some of them being exceptionally high in lime. The lake clays are generally less calcareous but locally, as in limestone areas, they may contain a large percentage of lime. The river silts are the least calcareous but they are usually gritty. On account of the generally high content of lime most of the clays burn white. In many deposits, however, there is an upper portion relatively free from lime which burns red, and a lower one very high in lime which burns white or cream color. The absence of lime in the upper zone is due to leaching.

The morainic or drift clays contain stone and pebbles, hence the name "boulder clay," and locally lime concretions. This necessitates screening. Screening and washing have been resorted to in some cases but the extra expense is generally prohibitive except in districts where good clays are wanting or where the clays possess exceptional burning qualities. The lake clays are comparatively free from pebbles and coarse sand but they may contain much very fine grit. These clays are generally suitable for making common brick and tile, and there are inexhaustible supplies of such clays in the eastern portion of the Southern Peninsula from Arenac county south to the Ohio boundary. Large areas of lake clays also occur in Chippewa and Ontonagon counties.

The morainic or boulder clays have been developed for the manufacture of common brick and tile at many places in the state but generally on a small scale. The lake clays in the vicinity of West Detroit have been developed very extensively for brick making and more than 82 per cent of the common brick produced in Michigan in 1914 were made in the vicinity of Detroit. Important developments have also been made near Paines and West Saginaw, Saginaw county, and at numerous places in Lenawee, Monroe, and Macomb counties.

In Ontonagon county some of the clays are of the slip variety and are suitable for glazing pottery. A deposit of slip clay is also reported near Harriette, Wexford county.

Most of the surface clays in Michigan are low grade and generally the mining of such clays is merely incidental to the manufacturing of common brick and tile. Nearly all of the clay sold as clay in Mich-

igan is slip clay mined chiefly near Rockland, Ontonagon county, and shipped to potteries in Ohio for glazing purposes. The great distance of the slip clay deposits from ready markets, however, makes development slow and difficult. A small amount of clay is sold for medicinal purposes.

PRODUCTION OF CLAY IN MICHIGAN, 1910-1914.

Year.	Slip clay.		Brick clay.		Miscellaneous clay.		Total.	
	Quantity.	Value.	Quantity.	Value	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.	
1910. . .	1,363	\$3,889	60	\$105	1	\$400	1,424	\$4,394
1911. . .	1,744	5,090	18	32	2	150	1,764	5,272
1912. . .	2,034	6,164	.....	.....	9	9	2,043	6,173
1913. . .	1,710	6,504	.....	.....	.....	.....	1,710	6,504
1914. . .	1,463	4,572	.....	.....	.....	.....	1,463	4,572
Total. .	8,314	\$26,219	.....	.....	.....	.....	8,404	\$26,915

## POTTERY.

From 1899 to 1904 the development of the pottery industry in Michigan was erratic, increasing from \$29,741 in 1899 to \$83,098 in 1902, and then decreasing to \$40,621 in 1904. From the latter year, however, the industry has made a substantial growth every year to 1914 when the production was the largest in its history. In 1909 the total value was \$95,439, in 1913 \$222,133, and in 1914 \$265,194, the value nearly trebling in five years. The production in 1914 represents a gain of \$43,061, or 17.8 per cent over that for 1913.

The principal products are red earthenware, chiefly flower pots, and porcelain electrical supplies. Of the five pottery firms three, the Detroit Flower Pot Co., Anton Hupprich of Detroit, and the Ionia Pottery Co, manufacture flower pots almost exclusively. The Jeffery-DeWitt Co., Detroit, manufactures various porcelain products—sanitary ware, insulators, tumbling jars, crucibles, etc., and the Pewabic Pottery & Tile Co., also in Detroit, art tile and miscellaneous ware. A new pottery firm, The Mount Clemens Pottery Co., according to reports, began operation in January, 1915, and will produce decorated ware.

Clays suitable for the manufacture of red earthenware are obtained in Michigan but the clays used for porcelain electrical supplies and white ware are imported from other states or countries.

## VALUE OF POTTERY PRODUCTS IN MICHIGAN, 1899-1914.

Year.	Rank of state.	No. firms.	Red earthen-ware, value.	Porcelain electrical supplies, value.	C. C. ware, value.	Miscellaneous, value.	Total value.	Gain per cent.	Per cent. of total product in U. S.
1899	18	4	\$29,641		\$100		\$29,741		17
1900	17	4	34,317				34,317	15.4	17
1901	16	5	42,465			\$2,400	44,865	30.2	20
1902	14	4	44,098			30,000	83,098	87.4	41
1903	19	4	42,007			6,000	48,007	-42.2	19
1904	17	4	40,621			3,000	43,621	-9.1	17
1905	17	5	*		*	7,000	45,961	4.5	16
1906	17	6	43,510			7,600	51,110	11.2	16
1907	16	6	54,474			7,100	61,574	18.5	20
1908	16	6	54,659			7,750	62,409	1.5	25
1909	13	5	60,939			34,500	95,439	52.0	31
1910	13	6	90,450			13,300	112,607	18.1	33
1911	13	6	80,580	*	*		130,490	15.8	34
1912	10	6	99,555	*	*		194,802	49.3	53
1913	10	5	65,000	*	*		222,133	20.8	59
1914	9	5	106,452	*	*		265,194	33.0	75
Totals							\$1,526,548		

\*Included in the total.

## BRICK AND TILE PRODUCTS.

*Raw Materials.*—Most of the surface clays (see Clay) in Michigan are low grade in character and are of three general classes, (1) morainic or drift clays, (2) lake clays and, (3) river silts. The morainic clays are generally high in lime and also contain sand and pebbles; the content of the latter giving rise to the term boulder clay. The lake clays are generally less calcareous, and likewise the river silts. Owing to the general gritty character or the high lime content, the clays are adapted chiefly for making common brick and tile. Due to their calcareous nature the clays burn cream or white in color. In some deposits however the lime has been removed by leaching to the depth of a few feet, and clay from this surface portion burns red.

Clay or shale deposits suitable for the manufacture of fire, vitrified and front brick, vitrified tile, fire-proofing, and other higher grade products are not abundant. Near Rockland, Ontonagon county, some of the clays belong to the slip varieties and are used for glazing purposes. At Grand Ledge, Jackson, Corunna, and near Bay City and Flushing shales belonging to the Coal Measures have been developed for vitrified and front brick, vitrified tile, sewer pipe, conduits, fire proofing, etc. A project for the development of shale deposits at Williamston for the manufacture of front brick is now under way, and during 1914 a new company, the Baker Clay Products Co., at Grand Ledge built a modern plant equipped with continuous kilns for the manufacture of vitrified products. According to reports the plant is now in operation.

Deposits of shale belonging to the Coldwater occur in the southeastern part of Huron county and in the vicinity of Coldwater, and some of these probably are suitable for making high grade products. The deposits are undeveloped as yet. Some of the shales associated with coal in the mines in Saginaw and Bay counties are apparently adapted for making vitrified products, but these have been exploited only near Bay City. Deposits of soft blue shale in the Traverse formation have been exposed in limestone quarries near Charlevoix and in the vicinity of Rockport, Alpena county, but these have not been developed. Numerous outcrops of these shales are also reported in the central part of Cheboygan county. The black shales of the Antrim exposed in a number of places in Alpena, Cheboygan and Charlevoix counties are probably too bituminous for making high grade clay products.

*Production.*—In 1914 the value of brick and tile products in Michigan exclusive of pottery was \$2,434,872 as compared with \$2,451,242 in 1913. This was a decrease of \$25,370 or 1.08 per cent from 1913 in spite of the fact that substantial gains were made in the production

and value of common and front brick, drain tile, and fire proofing. The chief losses were in the production of vitrified brick and fire brick, and miscellaneous products.

In 1914 Michigan ranked sixth in the number of common brick produced, sixth in value, and tenth in the total value of brick and tile products, exclusive of pottery.

The manufacture of common brick has made a great development in the vicinity of Detroit where suitable lake clays occur in great abundance. In 1914 Michigan produced 269,154,000 common brick of which 222,085,000, or 82.5 per cent were made in Wayne county. Drain tile is next to common brick in importance with a reported value of \$421,941, and vitrified brick or block third with a value of \$120,562. Sewer pipe is manufactured on a large scale at Grand Ledge and Jackson, but there are only two producers, hence no figures of production and value are given. Grand Ledge is also the chief center in the state for the production of drain tile.

NON-METALLIC MINERALS.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899-1914.

Year.	Common brick.		Average price per M.	Front brick.		Average price per M.	Vitrified brick.		Average price per M.	Fire brick.		Average price per M.
	Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.	
1899.....	200,144,000	\$933,176	\$4.66	4,290,000	\$58,920	\$13.73	*	*	\$12.42	.....	.....	.....
1900.....	180,892,000	863,250	4.77	8,421,000	48,411	5.75	*	*	.....	.....	.....	.....
1901.....	215,836,000	1,095,254	5.07	9,476,000	64,031	6.76	*	*	12.30	.....	.....	.....
1902.....	237,254,000	1,331,752	5.61	5,684,000	42,792	7.53	*	*	12.26	.....	.....	.....
1903.....	215,701,000	1,251,572	5.80	2,225,000	19,000	8.54	*	*	13.27	.....	.....	.....
1904.....	205,196,000	1,116,714	5.44	1,080,000	7,500	6.94	*	*	13.28	.....	.....	.....
1905.....	211,558,000	1,152,505	5.45	1,693,000	5,995	8.65	6,112,000	\$81,706	13.37	.....	.....	\$13.00
1906.....	206,583,000	1,178,202	5.70	1,474,000	14,162	9.61	6,239,000	81,814	13.13	.....	.....	19.37
1907.....	200,817,000	1,181,015	5.88	3,956,000	32,116	8.12	7,911,000	94,601	11.96	.....	.....	10.05
1908.....	181,049,000	994,525	5.49	1,898,000	18,496	10.28	6,165,000	76,630	12.43	.....	.....	12.00
1909.....	219,820,000	1,250,787	5.69	2,379,000	17,844	7.84	10,473,000	129,283	12.82	.....	.....	.....
1910.....	232,551,000	1,363,316	5.86	2,209,000	27,533	12.46	9,080,000	116,446	14.00	.....	.....	.....
1911.....	252,461,000	1,301,998	5.16	2,498,000	31,572	12.64	5,597,000	118,336	13.94	.....	.....	18.08
1912.....	271,189,000	1,592,283	5.87	3,934,000	41,476	10.54	6,600,000	92,000	14.71	*	*	17.78
1913.....	273,571,000	1,636,287	5.94	3,503,000	5,941	11.76	8,571,000	126,062	14.71	*	*	16.41
1914.....	269,154,000	1,633,216	6.07	1,488,000	21,121	14.19	7,733,000	120,562	15.59	*	*	19.78
Totals.....	3,573,870,000	\$19,865,852	.....	52,208,000	\$458,720	.....	74,471,000	\$997,440	.....	.....	.....	.....

\*Concealed, less than three producers.



MINERAL RESOURCES OF MICHIGAN.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899-1914

Year.	Store linings.		Drain tile.		Sewer pipe.		Fire-proofing.		Tile, not drain.		Miscellaneous.		Hollow building tile or blocks.		Per cent of total product in U. S.	Rank of state.	No of firms operating.	Total value.
	Value.		Value.		Value.		Value.		Value.		Value.		Value.					
1899			\$140,171		\$50,300		\$5,900				\$22,700				1.68	12	106	\$1,274,238
1900			115,747		57,916		7,350				408				1.70	12	180	1,117,378
1901			88,072		*		3,880				637				1.61	13	180	1,000,000
1902			86,642		*		3,280								1.58	13	179	1,000,000
1903			129,068		*		*								1.58	14	178	1,000,000
1904			208,068		*		*				\$10,188				1.58	14	104	1,070,809
1905			205,483		*		*				8,988				1.58	14	104	1,210,747
1906			314,068		*		*				3,583				1.58	14	104	1,210,747
1907			289,868		*		*				4,200				1.58	14	104	1,210,747
1908			327,630		*		4,100			1,500					1.50	17	132	1,280,000
1909			364,006		*		*			40,100					1.54	16	139	1,000,000
1910			348,205		*		*			66,128					1.54	16	139	1,000,000
1911		\$3,971	313,072		*		*								1.53	16	129	1,047,000
1912		*	387,945		*		*			228,530					1.53	13	111	1,000,000
1913		*	415,543		*		1,461			235,430					1.73	13	101	1,000,000
1914		*	421,941		*		3,752			360,000					1.73	13	105	1,000,000
Totals			\$4,175,404							234,280					1.88	10	100	\$20,070,081

\*Concealed under miscellaneous; less than three producers.

## SAND LIME BRICK.

The first sand-lime brick plant in the United States was started at Michigan City, Indiana, in 1901. The sand-lime brick industry was a "boom" industry and within two years nine plants were projected, building or in operation in Michigan. Under the erroneous impression that sand-lime brick satisfactory for all purposes could be made much more cheaply than ordinary brick, many plants were erected all over the country regardless of markets, transportation facilities, and competition with clay brick. The industry naturally suffered from the many failures consequent.

The sand-lime brick industry is more adapted to regions where good brick clays are absent and sand abundant. In Michigan most of the sand-lime brick plants were started in widely separated localities far from large clay working industries or near large cities which afforded a ready market for a limited output, hence the industry did not experience numerous failures and has maintained a relatively steady growth.

The growth has not been in an increased number of plants but in the average output per plant. In 1904 ten plants were in operation and produced nearly 10,000,000 common brick and 600,000 front and fancy brick valued at \$69,765. In 1905 twelve plants were in full operation and the production of common brick increased to 24,844,000 and face brick to 1,577,000 with a total value of \$169,302. Since 1905 the number of plants has remained about the same, fluctuating between ten and thirteen, but the production and value have greatly increased, reaching the maximum of 49,373,000 common brick and a total value of \$321,245 in 1913. In 1914, however, due to the general business depression throughout the country the production of common brick fell to 41,456,000 and the total value to \$255,784. This represents decreases of 7,817,000 in common brick and \$65,461 in total value. Of the twelve firms operating in 1914 eight reported decreases in sales and nine poorer to much poorer trade conditions owing to the great decrease in building operations in the state.

The production of front and fancy brick has fluctuated greatly, the former increasing from about 600,000 in 1904 to 2,000,000 in 1907, then decreasing the following year to 900,000 and reaching the maximum of 3,255,000 in 1910. During the last two years less than three companies manufactured front and fancy brick, hence figures have not been given. The evidence indicates that front or fancy sand-lime brick as manufactured are not as satisfactory for general purposes or cannot be produced as cheaply as clay front brick.

Since 1904 Michigan has held first rank in number of plants and total

production, and first in value with the exception of 1906 when it was exceeded by New York. For a number of years Michigan has produced nearly or more than twice as many sand-lime brick as any other state. In 1913 twelve plants were in operation as against five each for New York and California, the nearest competitors. In 1914, the number was the same, the Manistee Brick Company which went out of business being compensated for by a new firm, the Fairview Brick Company of Detroit. Two plants are located at Detroit and one each at Flint, Grand Rapids, Kalamazoo, Menominee, Ripley (Houghton county), Rives Junction (Jackson county), Rochester (Oakland county), Saginaw, Sebewaing (Huron county) and Sibley (Wayne county).

ANNUAL PRODUCTION AND VALUE OF SAND-LIME BRICK IN MICHIGAN AND UNITED STATES, 1904-1914.

Year.	No. of operating firms—Mich.	No. of operating firms reporting—('05)	Michigan production.						Total value Michigan.	Change per cent.—Michigan.	Total value United States.	Per cent of total production of U. S.	Rank.	
			Common brick.		Front brick.		Fancy brick.						Production.	Value.
			Quantity, (thousands).	Value.	Average price per thousand.	Quantity, (thousands).	Value.	Average price per thousand.	Quantity, (thousands).	Value.				
1904...	10	57	9,886	\$64,034	\$6 64	580	\$5,234	\$9 02	19	\$497	\$69,765	15.6	1	1
1905...	12	84	24,841	155,883	6 28	1,577	12,893	8 17	24	526	169,302	17.4	1	1
1906...	11	87	27,281	162,879	5 97	1,796	12,022	6 69	7	20	174,921	15.0	2	2
1907...	13	94	25,488	158,606	6 22	*2,000	14,234	7 17	...	...	172,840	14.1	1	1
1908...	10	87	21,997	131,827	5 99	*900	6,982	7 76	...	...	138,809	13.5	1	1
1909...	11	74	34,217	207,082	6 06	*1,600	11,144	6 97	...	...	218,226	19.0	1	1
1910...	10	76	37,648	218,627	5 81	3,256	22,022	6 76	...	...	240,649	20.5	1	1
1911...	10	66	32,880	192,224	5 84	2,726	17,777	6 52	...	...	210,001	23.4	1	1
1912...	11	71	48,129	307,106	6 38	1,163	9,626	8 27	...	...	316,732	25.9	1	1
1913...	12	68	49,373	315,882	6 40	†	†	†	†	†	321,245	25.9	1	1
1914...	12	62	41,456	248,113	5 98	†	†	†	†	†	255,784	23.5	1	1
Total...	...	...	353,205	\$2,162,263	\$6 12	...	...	...	...	...	\$2,288,274	...	...	...

\*Estimated. †Included in total.

## MINERAL AND SPRING WATERS.

The amount and value of mineral and spring waters produced in Michigan are subject to large fluctuations from year to year. The chief factors which influence the production are (1) business conditions and (2) local conditions affecting the quality of the municipal water supplies. The most pronounced decreases in production in Michigan occurred during the general depression in business in 1906 and 1907, and during the past two years there have been large decreases in great part due to poor trade conditions throughout the country. In certain cities the municipal water supplies are unsafe and as a consequence a thriving business of vending mineral and spring waters has grown up in these cities. During the past two or three years the municipal water supply in some cities has been greatly improved in quality through the development of new sources or the installation of filtration plants, as at Marquette and Grand Rapids.

Due to various causes, but largely to the gradual improvement in municipal water supplies, there has been a general though intermittent decrease in the production of mineral and spring waters since 1902, the production falling from 8,653,690 gallons in that year to only 884,893 gallons in 1913 valued at \$52,642. In 1914 there was a slight increase, the total output being 931,343 gallons valued at \$70,310. In 1914 there were 22 active springs as against 20 in 1913 and 28 in 1902.

## PRODUCTION AND VALUE OF MINERAL WATERS IN MICHIGAN, 1900-1914.

Year.	Rank.		No. of springs active.	Total.		Medicinal Value	Table Value.	Average price per gal.
	Quantity.	Value.		Quantity Gals.	Value.			
1900.....	6	4	28	3,398,996	\$411,935			\$0.121
1901.....	2	1	28	7,019,168	1,195,614			0.170
1902.....	1	0	28	8,653,690	275,763			0.032
1903.....	1	0	19	6,919,107	200,668			0.029
1904.....	7	13	19	3,385,675	118,422			0.035
1905.....	4	4	17	2,684,800	277,188	\$38,900	\$238,289	0.100
1906.....	13	23	19	902,528	73,357			0.081
1907.....	8	15	19	1,472,679	127,133	35,091	92,042	0.086
1908.....	8	16	24	2,004,433	88,910	5,995	82,915	0.044
1909.....	5	16	19	2,760,694	104,454	6,099	98,355	0.035
1910.....	9	17	17	1,454,020	69,538	100	69,438	0.048
1911.....	11	24	23	1,713,401	72,253	12,156	60,097	0.042
1912.....	12	19	17	1,420,465	75,611	777	74,834	0.053
1913.....	17	24	20	884,893	52,642	3,605	49,037	0.059
1914.....	16	20	22	931,343	70,310	12,252	58,058	0.075
Total.....				45,605,802	3,213,798	\$108,975	\$823,064	\$0.070

## NATURAL GAS.

Natural gas is produced chiefly in southeastern Michigan in Oakland, Macomb, and St. Clair counties, and in Manistee county. In the first two counties the gas occurs at shallow depths in the surface deposits in association with water. Apparently the source of the gas is from the underlying bituminous and petroliferous Devonian formations. The gas usually occurs in small volume and under small pressure, a well generally being sufficient to furnish only a farmhouse or two with heat and light for a few years. The average life of the wells is from six to ten years but some have been known to last 20 years or more; many others, however, play out in a few weeks or months. In Oakland, Macomb and Washtenaw counties some 25 or 30 of such wells are utilized by farmers for domestic purposes. According to reports many of the gas wells in the vicinity of Warren, Macomb county; and Royal Oak, Oakland county, have been declining rapidly in both volume and pressure during the past year.

Around Portage Lake, Manistee County, there are many artesian wells in the drift, which is locally 500 to 600 feet or over in depth. A number of these wells yield gas in association with water and one, the Onekama well, drilled by W. W. Davis in 1913 on the Northern Transportation Co. property near the fish hatchery yielded a large volume of gas at the depth of 437 feet under a pressure of 185 to 190 pounds per square inch. As far as known this well has not been utilized. Some of the other wells yield gas sufficient for heating and lighting a single dwelling and others only enough for a few lights.

At Port Huron many of the oil wells yield in addition to the oil very considerable quantities of gas known as "casing gas." The G. B. Stock wells, owned and operated by the Michigan Development Co., yield more than enough gas for pumping the wells. Some of the Michigan Central Oil & Gas Co. wells, two miles west of North Port Huron, are reported to yield from 20,000 to 40,000 cubic feet of gas per day and the work of laying a pipe line from the wells to Campau, a subdivision on the west side of Port Huron, is under way. At present the gas from two of the nine wells is much more than sufficient to fire the boiler used in drilling and to operate the gas engine for pumping the oil wells. The other wells are capped to prevent the loss of the gas. Some of the wells are reported to develop a rock pressure of over 250 pounds per square inch and when blown for some time, the pressure falls considerably but after closing the valves it requires but little over an hour for the wells to develop the maximum pressure. Recently the G. B. Stock Xylite Grease and Oil Co. drilled three oil wells on the Hoyt and Boyce plats about one-half mile southeast of the Stock

wells and all yield gas. One yields a very considerable quantity and the gas from the three wells is more than sufficient for operating purposes.

At the Draper Manufacturing Co. plant in North Port Huron opposite the entrance to St. Clair River a well was drilled in the winter of 1914 for oil and a small flow of oil and gas was struck at 564 feet. The gas is utilized in heating the boiler and, it is stated, furnishes daily heat equivalent to about 1,200 pounds of coal. The pressure is low, the maximum being only about 45 pounds which can be reduced to only about one pound in a few hours, if the burners are opened to their maximum capacity.

Several other wells in various parts of Port Huron yield small to considerable quantities of gas. Some are utilized for domestic purposes, but others have been abandoned, the gas being allowed to go to waste. In one or more instances the casings have been pulled and the wells abandoned without plugging. Water is thus allowed to enter the oil bearing rock and sooner or later serious injury must result to the oil field.

The gas and oil occur in the top of the Dundee limestone known locally as the "Lower Lime." The depth to the oil horizon in the Port Huron field ranges from about 500 to 710 feet. In some wells the gas occurs a few feet above the oil horizon, while in other wells the gas appears to be absorbed in the oil.

PRODUCTION OF NATURAL GAS IN MICHIGAN, 1911-1914.

Year.	No of producers.	Domestic.		Industrial.		Other.		Total.	
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
		M. cu. ft.		M. cu. ft.		M. cu. ft.		M. cu. ft.	
1911...	22	930	\$930			800	\$400	1,730	\$1,330
1912...	17		1,020	900	\$450			900	1,470
1913...								1,805	1,405
1914...								2,442	*1,642
Total...								6,877	\$5,847

\*Figure subject to revision.

## PETROLEUM.

Although oil has been struck in Michigan in small quantities in the vicinity of Port Huron, Allegan, Saginaw, and other places only at the former place have the quantities proved to be of commercial importance. A group of small oil wells have been operated in Port Huron for many years and during the past two or three years a considerable number of new wells have been drilled in various parts of the Port Huron field by different parties in further developing the local oil and gas possibilities.

## \*PORT HURON FIELD.

The early explorations for oil and gas in the Port Huron district were the direct results of the discoveries of oil in western Ontario. The Petrolia and Oil Springs fields were discovered in the early 60's. The longer axes of these fields are roughly parallel and extend in a nearly northwest-southeast direction. A third pool was discovered in 1886 in Euphemia township southeast of the Petrolia and Oil Springs pools and parallel to their longer axes. A line projected from the Euphemia pool northwest through the Oil Springs pool would pass in the vicinity of Sarnia and Port Huron and upon the supposition that other pools might be discovered along this line, explorations were made in Sarnia and Port Huron. In 1886-87 C. A. Bailey drilled a number of wells in the western part of the city. Small quantities of oil and gas were struck in the Dundee limestone, the top of which was struck at depths ranging from about 540 to 575 feet. The wells were not considered worthy of operation, and were abandoned. In 1887 F. L. Wells put down a test hole 1,685 feet in depth on the bank of Black river opposite Kerns Brewery and near Seventh Street Bridge. Only a show of oil and gas was struck.

No further attempts were made to develop the field until 1898 when G. B. Stock, an operator from the Ontario oil fields, organized the Michigan Development Company and drilled a number of wells in and about Port Huron. Most of the wells were drilled on what is known as the Goodrich property, a tract of about 15 acres in the western part of the city between the Grand Trunk railroad and Howard street. Oil in small but commercially important quantities were struck in all of the wells in the top of the Dundee which occurs in this part of the city at a depth of about 520 feet. At first some of the wells yielded two or three barrels per day, but gradually all of them decreased until

\*C. H. Gordon, Ann. Rept. Mich. Geol. Surv. for 1901, pp. 269-281.



the average daily production was only about one-half barrel per well. The decrease in many cases is due to the caving of the "soapstone" or soft calcareous shale of the Traverse formation, immediately overlying the Dundee.

With such shallow and cheap drilling the field was considered worthy of further development and new wells\* were drilled from time to time until there were some 21 wells on the Goodrich property ranging in depth from about 500 to 650 feet. Owing to caving and other causes, only about 15 of the wells are now in operation. All of the wells in addition to the oil yield more or less gas known as "casing gas" and it is more than sufficient to furnish motive power for a 25-horse power gas engine which pumps the wells.

The energetic example of Mr. Stock and the showings of oil in nearly all of the test wells incited other men to further explorations. A number of wells were drilled at various places in St. Clair county as at Abbottsford and in North Port Huron. Some of the holes were dry but most of them yielded small amounts of oil and gas, comparable in quantity to the Stock wells. About 1907 the Black River Oil & Gas Co. began explorations on the Henry May and Lawrence Gillette farms (Secs. 32 and 33, T. 7 N, R. 17 E.) on the north side of Water Street two miles west of North Port Huron and about two miles north-northwest of the Stock wells. Three or four wells were drilled and according to reports small quantities of both oil and gas were obtained. In 1912-1913 the Black River Oil & Gas Co. leases were taken over by the Michigan Central Oil & Gas Co. and more wells were drilled from time to time until at present there are nine wells on the May and Gillette farms. According to statements of officials of the company, all of the wells yield oil in small quantities varying from one-fourth to three barrels per day, and also very considerable quantities of gas. A number of the wells are said to yield from 20,000 to 40,000 feet of gas per day under a rock pressure varying from 125 to 250 pounds. After the wells have been blown some time the pressure is materially decreased but the maximum is regained in about one and one-quarter hours after the valves are closed.

On account of the small individual production of the wells pumping machinery and tankage were not installed until the spring of 1915. Up to the first of June only three wells had been put under operation and the total production from these to the above date was about 300 barrels. All of the wells are capped to prevent the escape of the "casing" gas and the supply of gas from two wells is stated to be more than sufficient for firing the boiler used for drilling and in operating a

\*For the record of these and other wells in the Port Huron field, see Publication 14, Geological Series 11. The Occurrence of Oil and Gas in Michigan, Chapter III; also Appendix, Ann. Rept. for 1901.

20 H. P. gas engine for pumping the oil wells. The quantity of gas from all of the wells has been deemed sufficient to warrant utilizing for village purposes and the work of laying a small pipe line is under way to furnish Campau, a small subdivision containing about 300 houses in the western part of Port Huron, with gas for heating.

The G. B. Stock Xylite Grease and Oil Co. in 1913 drilled three wells on the Boyce and Hoyt plats in the western part of Port Huron directly east of the Bailey and about one-half mile southeast of the Stock wells. The Boyce well according to statements of the officials of the company made an initial production of six or seven barrels per day but fell off rapidly to about two barrels or less. Of the two Hoyt wells one yields only a little oil but considerable gas and the other the most oil of the three wells. The gas is said to be more than sufficient for operating purposes.

In 1914 the Draper Manufacturing Co. of Port Huron drilled a test well at their plant near the foot of Church street in North Port Huron. In the Draper well some gas was struck in the Dundee limestone at 534 feet and a small quantity of oil at 564 feet. The gas was piped to the boiler and furnishes fuel equivalent to about 1,200 pounds of coal per day. The pressure is low, the maximum being only about 45 pounds and this can be reduced in a few hours to less than one pound if the burners are turned on to full capacity. The yield of oil is estimated at about one-eighth barrel per day. Mr. Thomas Draper, general manager of the company drilled a well on his farm, formerly known as the D. H. Bryce farm on the west side of Black River in the S. W.  $\frac{1}{4}$ , Sec. 27, T. 7 N., R. 17 E. The well was on the river flats 500 or 600 feet west of the entrance of the Black River drainage canal. The elevation of the top of the casing was about eight feet above the river or about 590 feet above sea level. According to Mr. Draper the Dundee limestone was struck at the depth of 549 feet or at a slightly lower elevation than in the Draper No. 1 at the plant to the southeast, or in the May and Gillette wells to the west. This indicates the presence of a shallow syncline. No oil or gas was struck though the well reached a depth of 700 feet and probably penetrated completely through the Dundee into the Monroe dolomites below. The Dundee was found to be composed of very hard gray to buff close grained limestone.

A careful log of the Draper No. 1 well was kept and a good set of samples preserved and Mr. Thos. Draper, manager of the company, kindly presented a copy of the record and a nearly complete duplicate set of samples to the Survey from which the following record was compiled:

## Draper Mfg. Company Well No. 1.

Port Huron, Mich.

Location: About 50 feet east of the boiler house of the Draper Mfg. Company's plant, located near the foot of Church street, North Port Huron, and 300 feet from and directly opposite the head of St. Clair River. Well began in January and finished February 20, 1914. Record by R. A. Smith from samples and log furnished by Thos. Draper, President of the Draper Mfg. Co.

## ELEVATION OF TOP OF CASING 587 FEET A. T.

	Thickness feet.	Depth feet.
Pleistocene or surface deposits:		
Sand and coarse gravel, heavily water bearing	40	40
Blue calcareous clay; viol. eff.	67	107
Sand and gravel, water bearing	1	108
Antrim shale:		
Brownish black bituminous shale, micaceous and pyritic	52	160
Grayish black bituminous shale, micaceous and pyritic	20	180
Traverse (Hamilton) formation:		
Hard cherty very pyritic, fossiliferous and finely crystalline ("top lime") limestone with "shells". Shells probably chert and seams of pyrite; viol. eff. <i>Atrypa reticularis</i> . Chert nodule at or just above 180 feet.	5	185
Soft gray and very calcareous shale or "soapstone." viol. eff.	40	225
Hard white and light gray crystalline limestone; viol. eff. <i>Atrypa reticularis</i> .	3	228
Limestone (sample missing).	17	245
Hard gray and white crystalline limestone; viol. eff. <i>Atrypa reticularis</i> .	15	260
Limestone (sample missing).	15	275
Very calcareous gray shale "soapstone" and gray argillaceous limestone.	5	280
Limestone (sample missing).	15	295
Very calcareous gray shale "soapstone" and gray argillaceous limestone.	5	300
"Soapstone," very calcareous gray shale (sample missing).	50	350
Very calcareous gray shale, "soapstone"	5	355
"Soapstone," very calcareous gray shale (sample missing).	45	400
Very calcareous gray shale, "soapstone"	5	405
"Soapstone," very calcareous gray shale (sample missing).	5	410
Dark gray argillaceous limestone, pyritic and fossiliferous ( <i>Atrypa</i> and corals).	5	415
"Soapstone," calcareous shale (sample missing).	30	445
Very calcareous gray shale, "soapstone," viol. eff.	5	450
"Soapstone," calcareous shale (sample missing).	15	465
Very calcareous gray shale, "soapstone" and hard gray crystalline limestone.	5	470
"Soapstone," calcareous shale (sample missing).	25	495
Very calcareous gray shale.	5	500
"Soapstone," calcareous shale.	11	511
Dundee (Onondaga, Corniferous) limestone:		
Light buff densely crystalline limestone; viol. eff. "Lower Lime".	17	528
Limestone (sample missing). Considerable gas at 534 ft.	6	534
Hard light buff dense grained limestone; viol. eff.	16	550
Grayish buff dense grained limestone; viol. eff. Oil at 564 ft.	18	568
Light grayish buff and white limestone; viol. eff.	7-6*	575-6*

\* Well shot with two light shots one just above and one just below the oil at 564 feet." Well yields gas equal to 1,200 lbs. of coal in firing the boiler, and about one-eighth barrel of oil per day. Well develops gas pressure of about 45 lbs. upon standing about 12 hours but this is reduced to less than one lb. after the valves of the gas jets have been open for a few hours.

Recently a well was put down by the Reed Wrecking Co. near their dry dock in South Port Huron, a record of which is given below. This

well is reported to yield much gas in spite of a heavy flow of water encountered in the top of the Dundee. According to reports attempts were made to case or plug off the water but these were unsuccessful.

### Reed Wrecking Company Well.

Port Huron, St. Clair Co.

Location: At Reed's dry dock in South Port Huron. Well completed in July, 1914. Driller's record.

ELEVATION ABOUT 590 (?) FEET A. T.

	Thickness feet.	Depth feet.
Pleistocene or glacial drift:		
Clay (12 inch hole) . . . . .	90	90
Antrim shale:		
Black shale (four and five-eighth inch hole) . . . . .	90	180
Traverse (Hamilton) formation:		
Soap . . . . .	21	201
Gray rock . . . . .	11	212
Soap . . . . .	8	220
Lime . . . . .	12	232
Soap . . . . .	21	253
Hard pan . . . . .	7	260
Soap . . . . .	7	267
Hard pan . . . . .	7	274
Soap . . . . .	12	286
Lime . . . . .	7	293
Bell (Marcellus) shale:		
Soap . . . . .	195	488
Dundee (Onondaga, Coralliferous limestone):		
Hard pan . . . . .	3	491
Lime (white) "Lower lime" ? . . . . .	3	494

"At ninety feet struck heavy flow surface gas and fresh water. Water came within 10 feet of surface. At 487 feet struck heavy flow of gas and salt water. We could not exhaust water by pumping, plugged last foot drilled but water still rose 450 feet. I think water is coming in with gas or else is coming from salt block which is about one mile from here. Gas pressure after water came within 50 feet of surface was 159 lbs. Gas was escaping at head. The gas attained a pressure of over 400 lbs. Finished in July, 1914."

Mr. C. M. Van Curen, President of the Michigan Central Oil & Mineral Company (formerly the Michigan Central Oil & Gas Company), kindly furnished the following record which is said to be representative of their wells on the May and Gillette farms.

### Gillette Well No. 3.

Port Huron.

Location: Near the west line of the Lawrence Gillette farm about 1,200 feet north of Water Street, about two miles west of Port Huron, in southwest one-fourth of Sec. 33, Port Huron Township (T. 7 N., R. 17 E.), St. Clair Co. Owners, Michigan Central Oil & Mineral Co. (C. M. Van Curen, Pres.; G. W. Van Curen, Mgr.) Record by Mr. Holme, driller.

## ELEVATION ABOUT 620 FEET A. T.

	Thickness feet.	Depth feet.
Pleistocene or glacial deposits:		
Clay . . . . .	115	115
Gravel . . . . .	6	121
Antrim shale:		
Black shale . . . . .	82	203
Brown soft shale . . . . .	27	230
Sharp gray rock . . . . .	5	235
Soap . . . . .	15	250
Lime (7 feet hard) . . . . .	10	260
Soap . . . . .	14	274
Hard pan . . . . .	6	280
Soap . . . . .	7	287
Hard pan . . . . .	3	290
Soap . . . . .	1	291
Middle lime . . . . .	25	316
Bell (Marcellus) shale:		
Soap . . . . .	239	555
Hard pan . . . . .	7	562
Soft oil rock . . . . .	15	577
Oil rock harder . . . . .	23	600
White lime . . . . .	7	607
Oil rock (hard) . . . . .	26	633

Several other wells in Port Huron drilled many years ago yield gas sufficient for domestic purposes and some of them have been utilized in this way. A well drilled a number of years ago by G. B. Stock on the G. F. Howe property near Kewahdin Beach in the northwest one-fourth, northeast one-fourth Sec. 22, Fort Gratiot Township north of Port Huron is reported to yield sufficient gas for several families. Gas in association with water was struck in the Traverse formation at the depth of 395 feet. The Dundee occurs at 574 feet or about 20 feet above sea level, or considerable lower than at the Draper No. 1 in North Port Huron or in the May and Gillette wells west of the city.

## G. F. Howe Well.

## North Port Huron.

Location: On Geo. F. Howe's property near Keewahdin Beach on northwest one-fourth, northeast one-fourth, Sec. 22, Fort Gratiot (T. 7 N., R. 17 E.) Township, St. Clair county. Drilled for oil and gas in 1903 by Wm. May. Record by R. A. Smith from driller's log furnished by Geo. F. Howe in 1915.

## ELEVATION APPROXIMATELY 595 FEET A. T.

	Thickness feet.	Depth feet.
<b>Pleistocene or glacial deposits:</b>		
Sand and gravel	14	14
Marl clay	50	64
Sticky blue clay	45	109
Surface gas. Six inch casing, five one-half inch drill.		
<b>Antrim shale:</b>		
Black shale	12	121
Brown shale	8	129
<b>Traverse (Hamilton) formation:</b>		
Brown limestone	65	194
White soapstone	8	202
Black sandstone	4	206
Brown limestone	16	222
Gray limestone	12	234
Soapstone	14	248
Gray limestone	26	274
White limestone	80	354
Soapstone	8	362
Gray limestone	16	378
Soapstone	8	386
Gray limestone	9	395
With gas and water.		
Soapstone	53	448
Gray limestone	13	461
Soapstone	23	484
Five inch casing, four one-half inch drill.		
Gray limestone	20	504
Soapstone	10	514
Brown limestone	8	522
Hard sandy shale	20	542
Dark sandy shale	32	574
<b>Dundee (Onondaga, Corniferous) limestone:</b>		
Brown limestone	7	581
Limestone "oil rock"	21	602

Well shot twice. Well is artesian and yields considerable gas which is utilized for domestic purposes. Pressure estimated at 40 to 50 lbs.

A report on the Port Huron oil field was published by C. H. Gordon in the Annual Report of the Michigan Geological Survey for 1901, and a second in 1911, by R. A. Smith in Publication 14, Geological Series 11. From the well records then available it appeared that a low anticlinal fold crossed St. Clair River from Sarnia through the southern part of Port Huron and then veering to the north-northwest through the western part of the city extended along Black River valley. The Bailey and Stock wells appeared to be near the crest of the anticline.

The more recent explorations by the Michigan Central Oil & Gas Company, now the Michigan Central Oil & Mineral Company, the Draper Manufacturing Co., the G. B. Stock Xylite Grease & Oil Co., and the Reed Wrecking Co. verify the above conclusions. The records of the above and older explorations show that an asymmetrical anticline crosses St. Clair River from Sarnia and, after passing through the southern part of Port Huron, veers toward the north-northwest through the western part of the city in the vicinity of the Bailey, Stock, and May and Gillette wells. The axis of the anticline if projected northward

would pass near Gardendale three miles north of the May and Gillette wells. Further explorations by the Michigan Central Oil & Mineral Co. are being made in this direction along the apparent crest of the anticline.

The western limb of the anticline (see fig. 24) is relatively steep, the dip from the Stock wells southwest to the Grand Trunk Junction well being more than 60 feet per mile. The eastern limb, however, is very gentle and extends into a shallow syncline running northeast in the vicinity of the Draper No. 2 and the G. F. Howe wells. The synclinal structure possibly accounts for the absence of oil in this well but the hard close grained character of the Dundee limestone encountered at this point would also account for this.

The surface deposits in the Port Huron field vary in depth from about 100 to 125 feet, and are chiefly clay with thin beds of sand and gravel which locally yield small quantities of gas. At the Draper Manufacturing Co. plant, however, 40 feet of very coarse gravel and heavily water bearing quicksand was penetrated before reaching the clay.

Directly beneath the drift there is also 80 to 180 feet of black bituminous shale belonging to the Antrim formation. The shale is thinnest along the crest of the anticline and it thickens rapidly to the west, southwest and south as shown by the Fair,\* Grand Trunk Junction, and Port Huron Salt Co. wells. According to Mr. Thos. Draper samples of black shale from the Draper No. 1 well were tested by a refining company at Petrolia, Ontario, and the yield of oil was reported to be about six and one-half gallons per ton. The Antrim shale from the Draper No. 1 well is less black and apparently less bituminous and petroliferous than in the May and Gillette well about three miles west.

The Traverse formation lies directly below the Antrim shale and consists of a series of limestones and soft calcareous blue shales from 270 to 350 feet in thickness, 325 feet being the average for the Stock, and May and Gillette wells. The top of the formation is a limestone known locally as the "Top lime." Near the center there is another well defined limestone horizon, the "Middle lime," and, at the base of the formation there is a heavy blue shale called the "Lower soap-rock." The "Top lime" locally yields considerable quantities of odorless gas. The "Soapstone" while comparatively soft is firm and "stands up" well in drilling but upon exposure to air and water it slacks quickly and caves. Until recently most of the wells have not been cased through the shale and as a consequence caving has ruined some of the wells and interfered greatly with the operation of others.

\*See Publication 14, Geol. Series 11, pp. 56-63. Mich. Geol. Surv.







Experience has shown that all wells should be cased through the shale.

The Dundee in the Port Huron field is a hard gray to buff bituminous limestone—the “Lower lime” of drillers, and the oil formation. Locally the Dundee is about 125 feet in thickness and the oil is generally struck in the upper 50 or 60 feet. Salt water is nearly always encountered in the lower part of the formation and sometimes very close to the top. The Draper No. 1 and some of the May and Gillette wells yield small quantities of brine along with the oil. According to reports, in the Reed Dry Dock well a heavy flow of brine was struck almost at the top of the Dundee.

The oil occurs in softer and more porous strata but the pores are generally small and scarcely visible to the naked eye. In the Port Huron field the Dundee contains a large amount of bituminous matter and oil, and if more open grained and porous areas could be discovered very probably good flows of oil would be obtained. The gas in some wells is struck a short distance above the oil horizon but in other places it is associated with the oil, apparently being absorbed in it.

According to Mr. Thos. Draper the oil tests about 34° Baume and is dark green in color and smells strongly of sulphur. It is a natural lubricant and is used by the G. B. Stock Xylite Grease & Oil Co. in the manufacture of a superior grade of lubricants.

Figure 24 is a map showing the contours of elevation for the top of the Dundee and the local structures in the rock strata.

#### Cadillac.

In 1914 the Cadillac Oil & Gas Co. attempted to test out the oil and gas possibilities of the Trenton at Cadillac. The drift was so thick and so much quicksand and water were struck that the greatest difficulty was experienced in getting down to rock. According to reports rock, a gray sandstone, apparently the Upper Marshall was struck at 795 feet. The enterprise was then abandoned.

If the depth to rock as reported is correct it is the greatest depth of drift yet penetrated in Michigan, 715 feet at Manistee being the greatest depth previously reported.

#### Dearborn.

At Dearborn, near Detroit, Mr. Henry Ford of the Ford Motor Co. of Detroit is drilling a very deep well for scientific purposes. Actual drilling began June 14, 1915, and by October 18 a depth of over 4,035 feet had been reached. The boring was started with a 14 inch casing and according to reports it is planned to drill to the depth of 5,000 feet or more, if possible. A careful log is being kept and samples taken

at every five feet. This well when completed will furnish definite information as to the character, thickness and depth of the various rock formations, and the location of the water, brine, salt, gas, oil and other mineral horizons down to the pre-Cambrian rocks which should, however, be struck at a depth considerably less than 5,000 feet.

## QUARTZ.

Vein quartz is mined near Ishpeming by the Michigan Quartz Silica Company of Milwaukee and ground chiefly for wood filler and paint. Some of the ground product is used in making polishes. The quartz rock is practically pure silica with only a trace of impurities and a little moisture. The mills are located at Ishpeming and Milwaukee.

## MINERAL PAINTS.

Soft iron ore is mined in Iron county and sold by Pickands Mather Company of Cleveland for the manufacture of paint. The Acme White Lead & Color Company of Detroit manufactures a large amount and a variety of mineral paints but the two firms given above are the only producers, hence statistics of production and value are not given.

## RELATIVE TO POSSIBLE POTASH DEPOSITS IN MICHIGAN.

For the past fifteen years Prof. A. W. Grabau of the department of geology of Columbia University, who is one of the foremost geologists and paleontologists in America, has been making a study of the Devonian and Silurian formations in Michigan. In 1900 Dr. Grabau began his work on the Traverse (Hamilton-Marcellus) formation of Michigan and the following year published the results of his investigations in the Annual Report of the Geological Survey of Michigan for 1901. In 1909 he and Dr. W. H. Sherzer published a joint report on the Monroe Formation, the Upper Silurian of Michigan. Since that date Dr. Grabau has been actively engaged in studying the Dundee (Onondaga) limestone and has a manuscript of nearly 600 pages on the Devonian formations of Michigan practically ready for the printer.

As a result of his long study of the Devonian and Silurian formations Dr. Grabau has concluded that there is a strong possibility that the Salina or Middle Silurian, the rock salt bearing formation, may contain potash bearing salts. Recently he communicated his belief in this possibility in a letter to R. C. Allen, State Geologist, from which the following is an excerpt:

"The present is a good time for the discovery of potash salts in Michigan. As I read the Silurian history, the lowest salt beds under Detroit ought to carry the potash salts similar to those found at Stassfurt the history being the same. This is true only for the lowest bed. If that does not contain it, then there is no potash in the deposits in the East [i. e. east of the Rocky Mountains]. I believe it is really worth making a test of this bed."

Potash salts are most extensively used in the United States in the

manufacture of fertilizers, glass, soaps, explosives, bleaching powder, dyestuffs and chemicals, and certain industries, notably the fertilizer industry, are vitally dependent upon these salts. The fertilizer and chemical industries have grown to enormous magnitude, yet they are dependent upon foreign sources for their supply of potash salts. Nearly all of the potash used in America is imported from Stassfurt, Germany, where potash salts occur in association with enormous deposits of rock salt. The present European war has cut off this supply and many fertilizer and chemical manufacturers have had to close or to curtail their output for want of raw material.

The importance of a reliable source of potash salts has become so great as to engage the attention of Congress, which in 1911 made specific appropriations to the United States Geological Survey for "determining the geological conditions favorable to the presence of potash salts" and to the Bureau of Soils for determining "a possible source of supply of potash, nitrates and other natural fertilizers." An examination of all of the brine and salt deposits was made but without success. A geologic study of ancient lake beds in the Great Basin was begun upon the theory that the salts contained in the waters of these lakes must have been deposited in their deepest portions, when the lakes were completely evaporated. By the close of 1913 seven test holes totalling more than 10,000 feet had been drilled in the ancient lake basins of Nevada without finding noteworthy traces of the coveted salts. A deposit of alunite, a potash bearing mineral, was discovered in Utah, but the amount of this substance available is relatively unimportant, being sufficient to furnish only a small fraction of the amount needed annually.

In southeastern Michigan from St. Clair to Monroe county and in western Ontario there are enormous deposits of rock salt. Several thousand square miles are known to be underlain with rock salt beds, which in the Detroit-St. Clair river area have an average aggregate thickness of nearly 400 feet. Rock salt is also known to occur in Manistee and Mason and in Alpena and Presque Isle counties. In the first two counties the salt beds have a total thickness of only about 40 feet but in the latter two the rock salt beds have their greatest known thickness, over 800 feet of rock salt having been penetrated in a deep well at Onaway, Presque Isle County. In southeastern Michigan the depth to the first salt beds varies from about 750 feet at Detroit to 1,500 or 1,600 feet at Port Huron, in Manistee and Mason counties, 1,975 to 2,300 feet, and in Alpena and Presque Isle counties, 1,000 to 1,630 feet. From geological considerations it is more than probable that the three known rock salt areas noted above are but parts of one

great rock salt area, covering most of the northern and eastern portions of the Southern Peninsula and western Ontario.

The beds of rock salt vary in thickness from a few inches to over 350 feet but the heaviest bed occurs near the bottom of the series and it is this bed which Dr. Grabau considers as a possible source of potash salts. The depth to this bed in Oakwood, a suburb of west Detroit, is 1,437 feet, at Wyandotte, about 1,100 feet; at Delray, 1,365 feet; at Fort Wayne, 1,445 feet; and at Royal Oak, 2,200 feet.

While the chances for finding potash in the salt beds of Michigan are apparently small, the great rewards for the successful explorer makes the proposition worthy of serious consideration, particularly in the light of Prof. Grabau's investigations and conclusions.

SUMMARY TABLE OF THE PRODUCTION AND VALUE OF

	1910.		1911.	
	Quantity.	Value.	Quantity.	Value.
Brick and tile products, number of brick	244,403,000	\$2,083,525	260,560,000	\$1,953,442
Brick, sand-lime, number of brick		240,649	35,615,000	210,001
Bromine	(a)	(a)	(a)	(a)
Calcium chloride	(a)	(a)	(a)	(a)
Cement, Portland; bbls. made, value cement shipped	3,687,719	3,378,940	3,686,716	3,024,676
Clay, tons		4,394	2,202	5,437
Coal, tons	1,534,967	2,930,771	1,476,074	2,791,461
Copper, lbs.	221,462,984	28,125,799	218,185,836	27,273,155
Graphite		(a)		(a)
Grindstones, tons		(a)		(a)
Gypsum and gypsum products, tons mined	357,174	668,201	347,296	573,926
*Iron ore, long tons	13,303,906	41,393,585	8,944,393	23,808,935
Iron, pig; long tons made; value pig iron shipped	307,975	(b)5,119,074	304,654	(b)4,672,799
Lime, tons made	72,345	303,377	80,709	352,608
Limestone		842,126		1,001,535
Mineral paints	(a)	(a)	(a)	(a)
Mineral and spring waters, gallons sold	1,454,020	69,538	1,713,401	72,253
Natural gas, M. cu. ft.		820		1,330
Petroleum		(a)		(a)
Pottery		112,697		130,490
Precious stones		(a)		(a)
Quartz		(a)		(a)
†Salt, bbls	9,452,022	2,231,262	10,320,074	2,633,155
Sand and gravel, tons	2,862,738	816,337	2,185,165	565,969
Sandstone		31,233		12,985
Silver, fine oz. Troy	262,200	141,600	507,700	274,100
Trap rock				51,000
Miscellaneous		278,442		161,030
Total		\$80,581,377		\$65,077,232

\*Figures from Iron Trade Review.

†Exclusive of bromine and calcium chloride.

(a) Included under miscellaneous.

(b) Excluded from total, covered by iron ore.

NON-METALLIC MINERALS.

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MINERAL PRODUCTS IN MICHIGAN, 1910-1914.

1912.		1913.		1914.	
Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
281,741,000	\$2,350,606	282,664,000	\$2,451,242	278,384,000	\$2,434,872
49,292,000	316,732	50,065,000	321,245	42,465,000	255,784
(a)	(a)	(a)	(a)	(a)	(a)
(a)	(a)	(a)	(a)	(a)	(a)
3,651,094	3,145,001	4,081,281	4,228,879	4,218,429	4,064,781
2,043	6,173	1,710	6,504	1,463	4,572
1,206,230	2,399,451	1,231,786	2,455,227		
218,138,408	35,992,837	183,853,409	28,442,806	158,009,748	21,426,122
	(a)		(a)		(a)
384,297	621,547	423,896	721,325	393,006	705,841
12,649,296	29,003,163	12,677,466	31,947,214	8,835,274	18,965,058
459,975	(b) 6,579,048	447,188	(b) 6,568,920	379,619	(b) 5,229,948
74,720	311,448	77,088	331,852	66,507	287,648
	1,139,560		1,408,708		1,457,961
(a)	(a)	(a)	(a)	(a)	(a)
1,420,465	75,611	884,893	52,642	931,343	70,310
900	1,470	1,805	1,405	2,442	1,642
	(a)		(a)		(a)
	194,892		222,883		265,194
	(a)		(a)		(a)
10,946,739	2,974,429	11,528,800	3,293,032	11,670,976	3,299,005
2,681,821	818,603	6,424,168	1,529,142	3,647,790	1,118,978
	16,438		19,224		(a)
528,453	324,999	295,173	178,284	413,500	228,665
	36,206		92,201		34,406
	522,141		540,626		565,147
	\$79,931,757		\$77,860,192		\$55,185,986





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## APPENDIX.

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DIRECTORY OF THE PRODUCERS OF NON-METALLIC  
MINERALS IN MICHIGAN, 1914.

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**BRICK AND TILE MANUFACTURERS, 1914.**

Operators.	Office.	Works.
<i>Allegan County:</i> Allegan Brick Works.....	Allegan	Allegan.
Cady, L. Y.....	Allegan	Allegan.
Zeeland Brick Co.....	Zeeland	Zeeland.
<i>Barry County:</i> Leonard, Wm.....	Delton	Delton.
<i>Bay County:</i> Michigan Vitrified Brick Co.....	Bay City	Bay City.
<i>Berrien County:</i> Mamer Brick Co.....	Benton Harbor	Benton Harbor.
<i>Branch County:</i> Reynolds & Son, Lorenzo D.....	Quincy	Algansee.
<i>Charlevoix County:</i> Boyne City Brick Co.....	Boyne City	Boyne City.
East Jordan Clay Products Co.....	East Jordan	East Jordan.
<i>Chippewa County:</i> Rudyard Brick Works.....	Rudyard	Rudyard.
<i>Dickinson County:</i> Vulcan Brick Works.....	Vulcan	Vulcan.
<i>Eaton County:</i> American Sewer Pipe Co.....	Broad St., Akron, Ohio	Grand Ledge.
Grand Ledge Clay Products Co.....	Grand Ledge	Grand Ledge.
<i>Emmet County:</i> De Arment, C. A.....	Petoskey	Petoskey.
<i>Genesee County:</i> Gale Bros.....	Atlas	Atlas.
Oliff, Thomas.....	Clio	Clio.
Uptegraff & Co., W. H.....	Flint	Davison.
Duffield Brick & Tile Works.....	Duffield	Duffield.
McCann, Fred'k W.....	Gaines	Gaines.
Otter Lake Brick & Tile Co.....	Otter Lake	Otter Lake.
Sharp, Frank.....	R. D. No. 1, Linden	South Mundy.
<i>Gladwin County:</i> Korkoske, Christ.....	Gladwin	Gladwin.
<i>Grand Traverse County:</i> Traverse City Brick Co.....	Traverse City	Keystone.
<i>Gratiot County:</i> Ashley Tile Co.....	Ashley	Ashley.
Stevenson & Sons, David.....	Ashley	Ashley.
Ithaca Brick & Tile Yards.....	Ithaca	Ithaca.
Lee, Chas.....	North Star	North Star.
Pest, C. D.....	North Star	North Star.
Smith & Sons, Wm. H. H.....	St. Louis	St. Louis.
Riverside Brick & Tile Co.....	Sumner	Sumner.
<i>Hillsdale County:</i> Jerome Brick & Tile Co.....	Jerome	Jerome.
Gish & Connor.....	Waldron	Waldron.
<i>Ingham County:</i> Clippert, Spaulding & Co.....	Lansing	Lansing.
<i>Ionia County:</i> Brown, Albert.....	Saranac	Saranac.
Van Der Heyden, Fred H.....	Ionia	Ionia.

## BRICK AND TILE MANUFACTURERS, 1914.—Continued.

Operators.	Office.	Works.
<i>Isabella County:</i>		
Kane Bros. ....	Mt. Pleasant. ....	Mt. Pleasant.
<i>Jackson County:</i>		
Simpson, Nathan F. Warden Michigan State Prison. ....	Jackson. ....	Jackson.
American Sewer Pipe Co. ....	Akron, Ohio. ....	Jackson.
<i>Kalamazoo County:</i>		
Zeeland Brick Co. ....	Zeeland. ....	Brownell.
<i>Kent County:</i>		
Grand Rapids Brick Co. ....	Mich. Ave. and Fuller St., Grand Rapids. ....	Grand Rapids.
Sparta Clay Works. ....	Sparta. ....	Sparta.
<i>Lenawee County:</i>		
Laurenson & Saunders. ....	Addison. ....	Addison.
Wilt, C. H. ....	Blissfield. ....	Blissfield.
Britton Pressed Brick Co. ....	Ann Arbor. ....	Britton.
Atkin, Wm. T. ....	Deerfield. ....	Deerfield.
Woodford & Son, B. F. ....	Jasper. ....	Jasper.
Ellis, G. D. ....	Macon. ....	Macon.
American Brick & Tile Co. ....	Morenci. ....	Morenci.
Comfort, Albert A. ....	R. D., Tecumseh. ....	Tecumseh.
<i>Macomb County:</i>		
Hartsig, Jacob. ....	Warren. ....	Centerline.
Hacker, Frank G. ....	Mt. Clemens. ....	Clinton.
Gass, East. ....	R. D. No. 2, Washington. ....	Davis.
Mt. Clemens Brick & Tile Co. ....	Mt. Clemens. ....	Mt. Clemens.
Warren Brick & Tile Works. ....	Warren. ....	Warren.
<i>Manistee County:</i>		
Kujawske, Joseph. ....	Oakhill. ....	Oakhill.
<i>Mecosta County:</i>		
Nehmer, Wm. F. ....	Big Rapids. ....	Big Rapids.
<i>Midland County:</i>		
Rilett & Herwig, J. W. ....	R. D. No. 3, Coleman. ....	Coleman.
Midland Tile Works. ....	Midland. ....	Midland.
<i>Monroe County:</i>		
Meyer Bros. ....	Azalla. ....	Azalla.
Linenfelter Brick & Tile Co. ....	Maybee. ....	Maybee.
Angerer Clay Products Co. ....	Scofield. ....	Scofield.
Strong & Son, John. ....	South Rockwood. ....	South Rockwood.
Hutel, John. ....	Azalla. ....	Azalla.
<i>Muskegon County:</i>		
Holton Brick Co. ....	Muskegon. ....	Holton.
<i>Newaygo County:</i>		
Stevens & Sons, Wm. ....	R. D., Grant. ....	Grant.
<i>Ottawa County:</i>		
Zeeland Brick Co. ....	Zeeland. ....	Zeeland.
<i>Saginaw County:</i>		
Parker-Lohmann Brick & Tile Co. ....	R. D. No. 10, Saginaw, W. S. ....	Saginaw, W. S.
Roble, Mrs. Peter. ....	R. D. No. 10, Saginaw, W. S. ....	Paines.
Sperry Bros. ....	Paines. ....	Paines.
Day, James. ....	R. D. No. 8, Saginaw. ....	Saginaw.
Day, Thomas. ....	R. D. No. 3, Saginaw. ....	Saginaw.
Saginaw Paving Brick Co. ....	1850 S. Jefferson Ave., Saginaw. ....	Saginaw.
<i>St. Clair County:</i>		
Belknap & Phillips. ....	Bell River Road, St. Clair. ....	St. Clair.
Beard, Fred'k. A. ....	Atkins, R. D. 2. ....	Ruby.
<i>Sanilac County:</i>		
Croswell Brick Co. ....	Croswell. ....	Croswell.
Minden City Brick & Tile Works. ....	Minden City. ....	Minden City.
Sandusky Brick & Tile Co. ....	Sandusky. ....	Sandusky.

BRICK AND TILE MANUFACTURERS, 1914.—*Concluded.*

Operators.	Office.	Works.
<i>Shiawassee County:</i> Detroit Vitrified Brick Co. ....	Box 289, Corunna. ....	Corunna.
<i>Tuscola County:</i> Thompson & Son, John. .... Hall, Chas. ....	Tuscola. .... Cass City. ....	Tuscola. Cass City.
<i>Van Buren County:</i> Stewart, James. ....	R. D. No. 2, Bangor. ....	Bangor.
<i>Wayne County:</i> Daniel & Bro. Brick Co., Jacob. .... Haggerty, John S. ....	291 Clippert Ave., Detroit. .... 1815 Dime Sav. Bk. Bldg., Detroit. ....	Detroit. Detroit.
Lonyo, Harsha Brick Co. ....	644 Humboldt Ave., Detroit. ....	Detroit.
McDonald & Son, John C. ....	707 Hammond Bldg., Detroit. ....	Springwells.
Ajax Brick Co. ....	66 Buhl Block, Detroit. ....	Detroit.
Bunte Bros. Tile Co. ....	Flat Rock. ....	Flat Rock.
Clippert & Bro. Brick Co., Geo. H. ....	1960 Michigan Ave., Detroit. ....	Springwells.
Clippert, Wm. ....	1960 Michigan Ave., Detroit. ....	Springwells.
Detroit Roofing Tile Co. ....	308 Hammond Bldg., Detroit. ....	Springwells.
Mercier, Bryan, Larkins Brick Co. ....	Michigan Ave. and Lonyo Road, Detroit. ....	Springwells.
Lonyo Bros. ....	613 Campbell Ave., Detroit. ....	Springwells.
Porath Bros. ....	306 Free Press Bldg., Detroit. ....	Springwells.
Sass Bros. & Stuve. ....	483 Lumley Ave., Detroit. ....	Springwells.
Springwells Brick Co. ....	1009 Hammond Bldg., Detroit. ....	Springwells.
Wolf Brick Co., F. H. ....	1487 Central Ave., Detroit. ....	Detroit.
Pewabic Pottery & Tile Co. ....	2161 Jefferson Ave., Detroit. ....	Detroit.

SAND-LIME BRICK PRODUCERS, 1914.

Operators.	Office.	Works.
<i>Genesee County:</i> Flint Sandstone Brick Co. ....	Flint. ....	Flint.
<i>Houghton County:</i> Lake Superior Stone Brick Co. ....	Calumet. ....	Ripley.
<i>Huron County:</i> Sebewaing Sandstone Brick Co. ....	Sebewaing. ....	Sebewaing.
<i>Jackson County:</i> Jackson-Lansing Brick Co. ....	Rives Junction. ....	Rives Junction.
<i>Kalamazoo County:</i> South Michigan Brick Co. ....	Kalamazoo. ....	Kalamazoo.
<i>Kent County:</i> Grande Brick Co. ....	Kalamazoo Ave., Grand Rapids. ....	Grand Rapids.
<i>Menominee County:</i> Menominee Brick Co. ....	Menominee. ....	Menominee.
<i>Oakland County:</i> Rochester Brick & Sand Co. ....	Rochester. ....	Rochester.
<i>Saginaw County:</i> Saginaw Brick Co. ....	321 N. Hamilton St., Saginaw. ....	Saginaw.
<i>Wayne County:</i> Michigan Pressed Brick Co. ....	Cor. Lawton Ave. and M. C. R. R., Detroit. ....	Detroit.
Church Brick Co. ....	Sibley. ....	Sibley.
Fairview Brick Co. ....	Foot of Jean St., Detroit. ....	Detroit.

## CEMENT PRODUCERS, 1914.

Operators.	Office.	Works.
Huron Portland Cement Co. ....	1525 Ford Bldg., Detroit.	Alpena.
Burt Portland Cement Co. ....	Bellevue	Bellevue.
Peninsular Portland Cement Co. ....	Cooley Block, Jackson	Cement City.
Michigan Portland Cement Co. ....	Chelsea	Four Mile Lake.
Wolverine Portland Cement Co. ....	Coldwater	Coldwater and Quincy.
New Aetna Portland Cement Co. ....	412 Union Trust Bldg., Detroit.	Fenton.
Omega Portland Cement Co. ....	Jonesville	Mosherville.
Newaygo Portland Cement Co. ....	Grand Rapids	Newaygo.
Peerless Portland Cement Co. ....	Union City	Union City.
Wyandotte Portland Cement Co. ....	1525 Ford Bldg., Detroit.	Wyandotte.
Egyptian Portland Cement Co. ....	Fenton	Fenton.

LIST OF MICHIGAN COAL MINES, LOCATION BY COUNTY, NAMES OF MANAGERS AND SUPERINTENDENTS.

Name of mine.	County.	Manager.	Address.	Superintendent.	Address.
Robert Gage Coal Co. No. 6.	Bay	Chas. Coryell	Bay City	H. C. Lewis	Bay City
Robert Gage Coal Co. No. 7.	Bay	Chas. Coryell	Bay City	John Coryell	Bay City
Monitor Mine.	Bay	Chas. Handy	Bay City	Jas. Love	Bay City
Beaver Coal Company.	Bay	Chas. Coryell	Bay City	John Coryell	Bay City
Wolverine Coal Mining Company No. 3.	Bay	R. M. Randall	Saginaw	Alex Liddle	Bay City
Wolverine Coal Mining Company No. 2.	Bay	R. M. Randall	Saginaw	Alex Liddle	Bay City
What Cheer Coal Mining Company No. 1.	Bay	E. B. Foss	Bay City	Alex Jeffreys	Bay City
Michigan Vitrifed Brick Company	Bay	Fred L. Twining	Bay City	John Harris	Bay City
Eben Wright Mine	Eaton	Eben Wright	Grand Ledge	Eben Wright	Grand Ledge
What Cheer Coal Mining Company No. 2.	Genesee	E. B. Foss	Bay City	Alex Jeffreys	Bay City
Cedar River Coal Mining Company	Ingham	Thos. M. Jenkins	Williamston	Thos. M. Jenkins	Williamston
Jenkins Coal Company	Jackson	Irving Jenkins	Jackson	Irving Jenkins	Jackson
Robert Gage Coal Company No. 2.	Saginaw	Chas. Coryell	Bay City	Richard Jenkins	St. Charles
Robert Gage Coal Company No. 3.	Saginaw	Chas. Coryell	Bay City	Henry Dause	St. Charles
Bliss Coal Mining Company	Saginaw	John T. Phillips	Saginaw	John E. Evans	Saginaw
Banner Coal Mining Company	Saginaw	Wm. B. Carmichael	Saginaw	Jos. Skillcorn	Swan Creek
Shlawassee Coal Mining Company	Saginaw	R. M. Randall	Swan Creek	Thos. Westwood	Swan Creek
Pere Marquette Coal Company No. 3.	Saginaw	R. M. Randall	Saginaw	R. Johnston	Saginaw
Chappell and Fordney No. 2.	Saginaw	R. M. Randall	Saginaw	Tim Hollis	Saginaw
Caledonia Coal Mining Company	Saginaw	John Dagan	Saginaw	Geo. Thedly	Saginaw
Savage Coal Mining Company	Saginaw	Ed. Savage	Saginaw	Fred Johnston	Saginaw
Detroit Vitrifed Brick Company	Shlawassee	J. W. DeBaubien	Detroit	H. Sarlazin	Corunna
Akron Coal Mining Company	Tuscola	Chas. Handy	Bay City (W. S.)	John Morris	Akron.

Hon. Thomas Canary, State Coal Mine Inspector, Saginaw, Michigan.



## CLAY MINERS, 1914.

Operators. ☛ ☛	Office.	Mine.
<i>Bay County:</i>		
Valley Land Co. ....	Bay City .....	Bay City.
<i>Ontonagon County:</i>		
Emmond, Wm. F. ....	Rockland .....	Rockland.
Robinson Clay Products Co. ....	1010 E. Market St., Akron, Ohio .....	Rockland.
Vogtlin, W. P. ....	Rockland .....	Rockland.
Jeffs, F. A. ....	Rockland .....	Rockland.
Jeffs Land Co., Ltd. ....	Rockland .....	Rockland.
<i>Wezford County:</i>		
Stanley & Son, J. Z. ....	Harriette .....	Harriette.

## COKE PRODUCERS, 1914.

Operators.	Address.	Location of plant.	No. of ovens.	County.
Michigan Alkali Co. ....	Wyandotte. ....	Plant No. 2 .....	30	Wayne.
Semet-Solvay Co. ....	Syracuse, N. Y. ....	Detroit .....	175	Wayne.

## NATURAL GAS PRODUCERS, 1914.

Operator.	Address.
<i>Bensie County:</i>	
Gordon & Conklin .....	Beulah.
<i>Hillsdale County:</i>	
DeWitt, C. M. ....	Osseo.
<i>Macomb County:</i>	
Hanekow, Mrs. Wm. H. ....	Warren, R. F. D. No. 2.
Hartsig, Wm. L. ....	Warren, R. F. D. No. 2.
Jacobs, Edward and Otto .....	Warren, R. F. D. No. 2.
Mielke, August .....	Warren, R. F. D. No. 2.
Smith, Alex. ....	Warren, R. F. D. No. 2.
Wolgast, Max .....	Warren, R. F. D. No. 2.
Elwart, Franz .....	Warren, R. F. D. No. 2.
<i>Oakland County:</i>	
Landau, Ed. ....	Royal Oak, R. D.
Langer, Henry .....	Royal Oak.
McClelland, James .....	Redford.
<i>St. Clair County:</i>	
Haas, H. G. ....	Port Huron, 1615 Griswold St.
Michigan Central Oil, Gas and Mineral Co .....	Port Huron.
Michigan Development Co. ....	Port Huron.
Stevens, H. Leroy .....	Port Huron.
Stock Co., G. B., Xylite Grease and Oil Co. ....	Port Huron.
Mason, F. H. ....	Port Huron, 2478 Military St.
Howe, Geo. W. ....	Port Huron, 4008 Military St.
<i>Washtenaw County:</i>	
Harmon, H. E. ....	Willis.
<i>Wayne County:</i>	
Becker, Irving .....	Redford.

GRAPHITE PRODUCERS, 1914.

Name.	Address.	Mine.
Detroit Graphite Co. ....	10, 12th St., Detroit.....	L'Anse.
Northern Graphite Co. ....	L'Anse.....	L'Anse.

GRINDSTONE AND SCYTHESTONE PRODUCERS, 1914.

Operator.	Office.	Quarry.
<i>Huron County:</i>		
Cleveland Stone Co. ....	Cleveland, Ohio.....	Grindstone City.
The Wallace Co. ....	Port Austin.....	Eagle Mills.
Cleveland Stone Co. ....	Cleveland, Ohio.....	Port Austin.

PRODUCERS OF GYPSUM PRODUCTS, 1914.

Operator.	Office.	Name of plant.	Location of mine.
United States Gypsum Co. ....	Chicago, Ill. ....	Alabaster.....	Alabaster.
United States Gypsum Co. ....	Chicago, Ill. ....	Midland.....	Grand Rapids.
Aeme Cement Plaster Co. ....	St. Louis, Mo. ....	Mill No. 5.....	Beverly.
Michigan Gypsum Co. ....	Grand Rapids.....	Grand Rapids.....	Grand Rapids.
American Cement Plaster Co. ....	Lawrence, Kas. ....	Grand Rapids.....	Grand Rapids.
Grand Rapids Plater Co. ....	427 Mich. Trust	Eagle Mill.....	Grand Rapids.
	Bldg., Gd. Rapids....	Grandville.....	Grandville.

## LIMESTONE AND LIME PRODUCERS, 1914.

Operators.	Office.	Quarry.
<i>Alpena County:</i>		
Collins, R. (also lime).....	151 Water St., Alpena.....	Alpena.
Michigan Alkali Co.....	Wyandotte.....	Wyandotte.
Great Lakes Stone and Lime Co..	Alpena.....	Rockport.
<i>Arenac County:</i>		
McDonnell, Jas. (lime).....	Twining.....	Omer.
<i>Charlevoix County:</i>		
Northern Lime Co. (lime).....	Petoskey.....	Bay Shore.
Charlevoix Rock Products Co. (also lime).....	Charlevoix.....	Charlevoix.
<i>Cheboygan County:</i>		
Campbell Stone Co. (also lime)...	Indian River.....	Afton.
Cheboygan Limestone Products Co	22 Pickering Bldg., Cincinnati, O.	Cheboygan.
<i>Delta County:</i>		
Delta Contracting Co.....	Escanaba.....	Escanaba (Hyde).
Bichler, John.....	Groos.....	Groos.
<i>Dickinson County:</i>		
Metronite Co., The.....	Milwaukee, Wis.....	Felch.
<i>Emmet County:</i>		
Antrim Lime Co. (lime).....	912 Mich. Trust Bldg., Grand Rapids.....	Petoskey.
Northern Lime Co. (also lime).....	Petoskey.....	Petoskey.
Petoskey Crushed Stone Co.....	Petoskey.....	Petoskey.
<i>Mackinac County:</i>		
Ozark Stone Quarry.....	Ozark.....	Ozark.
Union Carbide Co.....	42nd St. Bldg., New York, N. Y.	Hendrick's Quarry.
Fiborn Limestone Co.....	Sault Ste. Marie, Ontario, Can.	Fiborn Quarry.
<i>Marquette County:</i>		
City of Negaunee.....	Negaunee.....	Negaunee.
<i>Menominee County:</i>		
Menominee Stone Crusher.....	Menominee.....	Menominee.
<i>Monroe County:</i>		
Shore Line Stone Co.....	Monroe.....	Frenchtown.
The France Stone Co.....	1800 Second Nat'l Bank Bldg., Toledo, O.....	Monroe.
Morris, Sam W.....	Monroe.....	Monroe.
Wynocker, W.....	Samaria.....	Samaria.
<i>Presque Isle County:</i>		
Michigan Limestone & Chemical Co.....	55 Liberty St., New York, or Rogers City, Mich.....	Calcite.
<i>Schoolcraft County:</i>		
The White Marble Lime Co.....	Manistique.....	Blaney, Manistique and Marblehead.
Delta Contracting Co.....	(Also lime)..... Escanaba.....	Manistique.
<i>Wayne County:</i>		
Solvay Process Co.....	Syracuse, N. Y.....	Trenton and Sibley.
Dunbar Stone Co.....	Detroit or River Rouge.....	Mouth of Detroit River.

## MINERAL PAINT PRODUCERS, 1914.

Operator.	Pigment.	Office.	Location of plant.
Acme White Lead & Color Works.....	White lead, red lead, litharge, orange mineral.....	Detroit.....	Detroit.
Pickands, Mather & Co..	Met. Point.....	Cleveland, Ohio.	Iron County.

MINERAL AND SPRING WATER PRODUCERS, 1914.

Operators.	Office.	Spring.
Arctic Spring Water Co. ....	412 Ottawa Ave., Grand Rapids .....	Arctic. Alden. Beaver.
Bailey Marvel Springs Co. ....	Bellaire .....	Bromo-Hygela. Charlevoix.
Willis, J. L. ....	Bangor .....	Cooper Farm Spring.
Bromo-Hygela Mineral Water Co. ....	Coldwater .....	Crystal Spring. Eastman.
Charlevoix Mineral Water Co. ....	Charlevoix .....	Giant Spring.
Walker Gordon Farm & Laboratory Co. ....	Birmingham .....	Harrison. Lake Superior Mineral Spring.
Crystal Spring Water, Fuel & Ice Co. ....	35 No. Division St., Grand Rapids .....	Mt. Clemens Crystal Spring. Ogemaw.
Eastman Springs Co. ....	Benton Harbor .....	Osseo. Ponce de Leon.
Detroit Mineral Water Co. ....	584 Michigan Ave., Detroit .....	Sanitas. Victory.
Harrison Spring Water Co. ....	360 W. Bridge St., Grand Rapids .....	White Oak. Moorman Well.
Polaris Water Co. ....	Marquette .....	Andrew's Magnetic Mineral.
Mt. Clemens Crystal Springs Water Co. ....	Mt. Clemens .....	Avoca. Maple Leaf Springs.
Ogemaw Spring Water Co. ....	Bay City .....	Panacea. Salutaris.
Dewitt, C. M. ....	Osseo .....	Welcome Island. Crystal. Sterling.
Ponce de Leon Co. ....	Grand Rapids .....	Sultana.
Pike, Lute H. ....	Topinabee .....	
Shorkey, Chas. ....	Mt. Clemens .....	
Coca-Cola Bottling Co. ....	Battle Creek .....	
Ypsilanti Mineral Water & Bath Co. ....	Ypsilanti .....	
Magnetic Spring Water Co. ....	Saginaw, W. S. ....	
Beard Hills Mineral Spring Co. ....	105 E. Bancroft St., Toledo, Ohio .....	
Charbeneau, Jno. H. ....	Mt. Clemens .....	
Preussel, Frank W. ....	47 Crocker Ave., Mt. Clemens .....	
Salutaris Water Co. ....	Detroit .....	
Oliver Co. ....	Pontiac .....	
Wall, W. J. ....	South Haven .....	
Jackson, Roger .....	Crystal Falls .....	
Sutton, Geo. ....	Hartford .....	

PETROLEUM PRODUCERS, 1914.

Operators.	Address.
Michigan Central Oil & Mineral Co. ....	807 Pine St., Port Huron.
Michigan Development Co. ....	103 Huron Ave., Port Huron.
Stock Xylite Grease & Oil Co., G. B. ....	Port Huron.

PIG IRON PRODUCERS, 1914.

Operator.	Office.	Name of furnace.	Location of furnace.
Lake Superior Iron & Chemical Co. ....	Detroit .....	Boyer City .....	Boyer City.
Lake Superior Iron & Chemical Co. ....	Detroit .....	Chocolay .....	Chocolay.
Lake Superior Iron & Chemical Co. ....	Detroit .....	Elk Rapids .....	Elk Rapids.
Lake Superior Iron & Chemical Co. ....	Detroit .....	Manistique .....	Manistique.
Lake Superior Iron & Chemical Co. ....	Detroit .....	Newberry .....	Newberry.
Mitchell-Diggins Iron Co. ....	Cadillac .....	Cadillac .....	Cadillac.
Detroit Furnace Co. ....	1069 Jefferson Ave., Detroit .....	Detroit .....	Detroit.
Detroit Iron & Steel Co. ....	149 Jefferson Ave., Detroit .....	A & B .....	Detroit
East Jordan Furnace Co. ....	East Jordan .....	Pioneer No. 1 .....	East Jordan.
Cleveland Cliffs Iron Co. ....	Cleveland, Ohio .....		Gladstone.
Antrim Iron Co. ....	Antrim .....	Antrim .....	Antrim.
Pioneer Iron Co. ....	Marquette .....	Carp .....	Near Marquette.
Pioneer Iron Co. ....	Marquette .....	Pioneer No. 2 .....	Near Marquette.
Stevenson Charcoal Iron Co. ....		Stevenson .....	Wells.

## POTTERY PRODUCERS, 1914.

Operator.	Office.	Works.
<i>Ionia County:</i>		
Ionia Pottery Co. ....	Ionia .....	Ionia.
<i>Wayne County:</i>		
Detroit Flower Pot Co. ....	490 Howard St., Detroit, .....	Detroit.
Jeffery-Dewitt Co. ....	Detroit .....	Detroit.
Hupprich, Anton. ....	2161 Michigan Ave., Detroit. ....	Detroit.
Mt. Clemens Pottery Co. ....	Mt. Clemens. ....	Mt. Clemens.
Pewabic Pottery & Tile Co. ....	2161 Jefferson St., Detroit. ....	Detroit.

## QUARTZ PRODUCERS, 1914.

Operator.	Office.	Mine.
<i>Marquette County:</i>		
Michigan Quartz Silica Co. ....	Milwaukee, Wis. ....	Ishpeming.

## SALT PRODUCERS, 1914.

Operators.	Office.	Works.
<i>Bay County:</i>		
Hine Lumber Co. ....	Sta., A. Bay City .....	W. Bay City.
<i>Isabella County:</i>		
Van Schaack & Sons, Peter. ....	118 Lake St., Chicago, Ill. ....	Mt. Pleasant.
<i>Manistee County:</i>		
Peters Salt & Lumber Co., R. G. ....	East Lake. ....	East Lake.
Filer & Sons, Vacuum Pan Salt Wks. ....	Filer City. ....	Filer City.
The Buckley & Douglass Lumber Co. ....	381 River St., Manistee. ....	Manistee.
Sands Salt & Lumber Co., Louis. ....	Manistee. ....	Manistee.
<i>Mason County:</i>		
Anchor Salt Co. ....	Ludington. ....	Ludington.
Stearns Salt & Lumber Co. ....	Ludington. ....	Ludington.
<i>Midland County:</i>		
The Dow Chemical Co. ....	Midland. ....	Midland.
<i>Saginaw County:</i>		
Mershon, Eddy, Parker & Co. ....	Saginaw. ....	Carrollton
Bliss & Van Auken Lumber Co. ....	Saginaw, W. S. ....	Saginaw.
Eastman Flooring Co., S. L. ....	Saginaw, W. S. ....	Saginaw.
Estate of Edward Germain. ....	Holland Ave. near Genesee St., Saginaw, E. S. ....	Saginaw.
Saginaw Plate Glass Co. ....	Saginaw, W. S. ....	Saginaw.
Saginaw Salt Co. ....	430 Shearer Bldg., Bay City. ....	St. Charles.
<i>St. Clair County:</i>		
Michigan Salt Works. ....	Marine City. ....	Marine City.
Morton Salt Co. ....	717 Ry. Ex., Chicago, Ill. ....	Port Huron.
Diamond Crystals Salt Co. ....	St. Clair. ....	Port Huron.
Marine City Salt Co. ....	Marine City. ....	Marine City.
<i>Wayne County:</i>		
Inland Delray Salt Co. ....	Detroit. ....	Delray.
Solvay Process Co. ....	Detroit. ....	Delray.
Detroit Rock Salt Co. ....	Scranton, Pa. ....	Detroit.
Mulkey Salt Co. ....	610 Equity Bldg., Detroit. ....	Oakwood.
Kay Salt Co. ....	Charleston, W. Va. ....	Ecorse.
Worcester Salt Co. ....	168 Duane St., New York, N. Y. ....	Ecorse.
Michigan Alkali Co. ....	Wyandotte. ....	Wyandotte.
Pennsylvania Salt Mfg. Co. ....	115 Chestnut St., Philadelphia, Pa. ....	Wyandotte.

## SANDSTONE PRODUCERS, 1914.

Operator.	Office.	Quarry.
<i>Houghton County:</i> Portage Entry Redstone Co.....	Jacobsville.....	Jacobsville.
<i>Huron County:</i> Cleveland Stone Co.....	Cleveland, Ohio.....	Grindstone.
<i>Monroe County:</i> Strouse, J. D.....	Ottawa Lake.....	Ottawa Lake.

## SAND AND GRAVEL PRODUCERS, 1914.

Operator.	Office.	Pit.
<i>Allegan County:</i>		
Sutler, Fred W.	Byron Center.	Burnips Corners.
West, Peter	Dorr, R. F. D. 2	Dorr.
Terpstra, Geo.	Dunningville, R. F. D. 1.	Dunningville.
Wheeler, Mrs. J. C.	Martin	Martin.
Kool, Henry	New Richmond	New Richmond.
Pierce, Myron	Otsego	Otsego.
Powell, J. C.	Plainwell	Plainwell.
Craim, W. C.	Douglass	Douglass.
<i>Alpena County:</i>		
Riley & Monkman	501 State St., Alpena	Alpena.
<i>Antrim County:</i>		
Hilton, Robert	Bellaire, R. F. D. 1.	Bellaire.
Sissons, F. E.	Central Lake, R. F. D. 1.	Central Lake.
McPherson, Guy	Eastport	Eastport.
Campbell, W.	Mancelona	Mancelona.
Swan, Guy	Mancelona	Mancelona.
<i>Arenac County:</i>		
Wells, A. H.	Standish, R. D. 2	Standish.
Daniels, Wm.	Sterling, R. F. D.	Sterling.
Pettit, Frank	Twining, R. F. D. 1	Twining.
Rogers, Sidney	Twining	Twining.
Mayer of Omer City	Omer	Omer.
<i>Barry County:</i>		
Woolston, Chas.	Hastings	Hastings.
Hitt, Geo.	Woodland	Woodland.
Renkes, Fred	Hastings	Hastings.
Dunham, F. O.	Nashville	Grove Center.
<i>Bay County:</i>		
Hayward, R.	Bay City, R. F. D. 3	Bay City.
<i>Benzie County:</i>		
Huddleston, Wm.	Bendon, R. F. D. 1.	Bendon.
Rice, J. R.	Benzonina, R. F. D. 1.	Benzonina.
Wilson Bros.	Lake Ann	Lake Ann.
Betsey River Orchards, Ben Newhall & Co.	840 Ohio Bldg, Chicago, or Thompsonville, Mich	Thompsonville.
<i>Berrien County:</i>		
Edgecombe, Geo. W.	439 Main St., Benton Harbor	Benton Harbor.
Warren, Paul Co.	Lakeside	Lakeside.
Benton Harbor Sand Co.	Benton Harbor	Benton Harbor.
American Sand & Gravel Co.	Benton Harbor	Benton Harbor.
Garden City Sand Co.	Riverside	Riverside.
Kerlikowske Bros.	St. Joseph	St. Joseph.
Brown, H. C.	Berrien Springs	Baroda.
Brewer, Frank	Galien	Galien.
<i>Branch County:</i>		
Werner, Jake	Bronson	Bronson.
Hoyt, Moses	Coldwater	Coldwater.
Barnes, Mrs. J. M.	Montgomery	Kinderhook.
<i>Calhoun County:</i>		
March, Andrew	Union City, R. F. D. 5	Union City.
Ringler, A.	Albion, R. F. D. 2	Albion.
Young, Willard A.	Albion	Albion.
Blowers, N. A.	Athens	Athens.
Marrow, D. G.	Battle Creek	Athens.
Ellis, Bert	Battle Creek	Battle Creek.
Funk, F. J.	Battle Creek, R. F. D. 2	Battle Creek.
Hiscock, Seth	Battle Creek	Battle Creek.
Webb, Mrs. N. E.	Battle Creek, R. F. D. 11	Battle Creek.
Grosbeck, Fred	Burlington	Burlington.
Adrian, John	323 Hamblin Ave.	Battle Creek.
Crystal Sand & Gravel Co.	12 E. Main St., Battle Creek	Battle Creek.
Brownlee Park & Material Co.	Battle Creek	Brownlee Park.
Michigan United Traction Co.	Jackson	Marshall.
Prince, Wm. A.	Ceresco	Ceresco.

SAND AND GRAVEL PRODUCERS, 1914.—Continued.

Operator.	Office.	Plt.
<i>Cass County:</i> McNab, M. . . . . Thorp, Mrs. L. S. . . . .	Cassopolis . . . . . Niles . . . . .	Cassopolis. Cassopolis.
<i>Charlevoix County:</i> Healy, Chas. . . . .	East Jordan, R. F. D. 2 . . . . .	East Jordan.
<i>Cheboygan County:</i> Charpointier, Jos. . . . .	Cheboygan, R. F. D. 2 . . . . .	Cheboygan.
<i>Chippewa County:</i> Taylor, F. H. . . . . Belanger, Louis. . . . . Rye, Jas. . . . .	Pickford . . . . . Sault Ste. Marie . . . . . 409 Maple St., Sault Ste. Marie . . . . .	Pickford. Sault Ste. Marie. Sault Ste. Marie.
<i>Clare County:</i> Littlefield, J. L. . . . .	Farwell . . . . .	Farwell.
<i>Clinton County:</i> Parmenter, Geo. . . . . Gleason, S. B. . . . . Allen, Frank . . . . . Keys, Hiram . . . . . Wilhelm, Noah . . . . . Lerg, John A. . . . . Mich. United Traction Co. . . . . Stowell, Elmer . . . . . Ott, Geo. . . . . Coats, Lewey . . . . .	Shepardsville . . . . . Ovid . . . . . Elsie . . . . . St. Johns . . . . . Bath, R. D. . . . . DeWitt, R. F. D. 26 . . . . . Jackson . . . . . Ovid . . . . . DeWitt . . . . . Ovid . . . . .	Shepardsville. Ovid. Elsie. St. Johns. Bath. DeWitt. DeWitt. Ovid. DeWitt. Ovid.
<i>Crawford County:</i> Latham, Nathan J. . . . .	Grayling . . . . .	Grayling.
<i>Delta County:</i> Putvin, Louis . . . . . Chicago & N. W. R. R. . . . . Escanaba Stone & Gravel Co. . . . . Jorgensen, Adolph . . . . .	Garden . . . . . Chicago . . . . . Escanaba . . . . . Escanaba . . . . .	Garden. Escanaba. Escanaba, Flat Rock. Escanaba.
<i>Dickinson County:</i> Chicago & N. W. R. R. . . . . Vulcan Brick Works . . . . .	Chicago . . . . . Vulcan . . . . .	Iron Mountain and Loretto. Vulcan.
<i>Eaton County:</i> Palmiter, S. J. . . . . Hull Bros. . . . . Johnson, C. . . . . Divine & Co., Wm. . . . . Frost, C. A. . . . . Kent, V. M. . . . . Saier, H. E. . . . . Cheal, J. E. . . . . Wells, C. E. . . . .	Bellevue, R. F. D. 4 . . . . . Dimondale . . . . . Eaton Rapids . . . . . Grand Ledge . . . . . Grand Ledge . . . . . Grand Ledge . . . . . Lansing, R. F. D. 6 . . . . . Sunfield . . . . . Vermontville . . . . .	Bellevue. Dimondale. Eaton Rapids. Grand Ledge. Grand Ledge. Grand Ledge. Millet. Sunfield. Vermontville.
<i>Genesee County:</i> Bird, Jos. . . . . Burns, Ed. . . . . Farnham, Henry . . . . . Flint Sandstone Brick Co. . . . . Reid, Alfred . . . . . Scott, F. D. . . . . Boston, H. W. . . . . Brocker, August . . . . . Stine, Martin . . . . . Bowles, E. . . . . Hogan, Daniel . . . . . Fletcher, Seward . . . . . Sansan, Geo. . . . . Brown, D. . . . . Johnson, Ernie . . . . .	Davison . . . . . Duffield . . . . . Farnham, R. F. D. 3 . . . . . Flint . . . . . Flint . . . . . Genesee . . . . . Goodrich, R. F. D. 1 . . . . . Goodrich . . . . . Goodrich . . . . . Goodrich . . . . . Linden . . . . . Linden . . . . . Linden . . . . . Linden . . . . . Linden . . . . . Linden . . . . . Swartz Creek . . . . . Swartz Creek . . . . .	Davison. Duffield. Fenton. Flint. Flint. Genesee. Goodrich. Goodrich. Goodrich. Goodrich. Linden. Linden. Linden. Linden. Linden. Linden. Swartz Creek. Swartz Creek.
<i>Gladwin County:</i> Wenzel, John . . . . .	Beaverton, R. F. D. 1 . . . . .	Beaverton.



## SAND AND GRAVEL PRODUCERS, 1914.—Continued.

Operator.	Office.	Pit.
<i>Gogebic County:</i>		
Chicago & N. W. R. R. ....	Chicago .....	Blomers.
<i>Grand Traverse County:</i>		
Koch, John .....	Mayfield .....	Mayfield.
<i>Graziot County:</i>		
Church, J. H. ....	Alma .....	Alma.
Sawvel, Robert .....	Breckenridge .....	Breckenridge.
Lippert, Jacob .....	Elwell .....	Elwell.
Curtis, C. ....	Ithaca, R. F. D. 6. ....	Ithaca.
Haas Bros. ....	Northstar, R. F. D. 3. ....	Northstar.
Tomlin, A. ....	Sumner .....	Sumner.
Wiles, Wm. ....	Sumner, R. F. D. 2. ....	Sumner.
<i>Hillsdale County:</i>		
Crowl, A. ....	Camden .....	Camden.
Morgan, H. C. ....	Camden, R. F. D. 37. ....	Camden.
Sholfeld, H. C. ....	Pittsford .....	Pittsford.
Thompson, L. W. ....	Waldron .....	Waldron.
Wolcott, C. Nelson E. ....	Hillsdale .....	Hillsdale.
<i>Houghton County:</i>		
Winona Copper Co. ....	Winona .....	Winona.
<i>Huron County:</i>		
Conkey, Sam. ....	Caseville .....	Caseville.
Merrick Gravel Co. ....	Pigeon .....	Pigeon.
Wallace Co. The. ....	Port Austin .....	Port Austin.
Haskell, Miss Eliz. A. ....	Port Austin .....	Port Austin.
<i>Ingham County:</i>		
Artz, Joe. ....	Leslie .....	Sec. 23, Bunker Hill Twp.
Atkinson, Mr. ....	Mason .....	S. W. Cor. Sec. 16, Vevay Twp.
Bell, O. E. ....	Mason or Lansing. ....	Sec. 36, Delhi Twp.
Breitenwischer, Lewis. ....	Lansing .....	Lansing.
Bunker, Chas. ....	Leslie or Stockbridge. ....	Sec. 35, Bunker Hill Twp.
Corwin, W. L. ....	Williamston .....	Sec. 2, Wheatfield Twp.
Couch, Chas. ....	Mason .....	Sec. 25, Aurelius Twp.
Curtiss, Bert. ....	Williamston .....	N. E. Cor. Sec. 21, Wheatfield Twp.
Potts, W. S. ....	Mason, R. F. D. 1. ....	Mason.
Dubois, D. D. ....	Leslie .....	Sec. 28, Bunker Hill Twp.
Frost, A. J. ....	Williamston .....	Sec. 22, Wheatfield Twp.
Frost, J. F. ....	Williamston .....	Sec. 26, Wheatfield Twp.
Holbrook, John. ....	Lansing .....	Lansing (Holt).
Linn, Lew. ....	Williamston .....	Sec. 15, Wheatfield Twp.
Saler, H. E. ....	Lansing, R. F. D. 6. ....	Lansing.
Stockman, F. M. ....	Lansing .....	Lansing.
Shortwell, E. ....	Leslie (or Stockbridge). ....	Sec. 35, Bunker Hill Twp.
Campbell, Hugh. ....	1516 6th St., Bay City. ....	Mason.
Nice, Geo. ....	Mason .....	Sec. 6, Vevay Twp.
Okobock, Dennis. ....	Mason .....	Sec. 5, Vevay Twp.
Potts, Walter F. ....	Mason, R. F. D. 1. ....	Mason.
Rappe, A. ....	Lansing or E. Lansing. ....	Sec. 16, Meridian Twp.
Roark, J. C. ....	Williamston .....	Sec. 34, Williamston Twp.
Sheltraw, A. E. ....	Saginaw .....	Mason.
Smith, Geo. ....	Mason .....	Sec. 10, Vevay Twp.
Stevens, F. B. ....	Mason .....	Sec. 5, Vevay Twp.
Victory, Ward. ....	Leslie or Stockbridge. ....	Sec. 36, Bunker Hill Twp.
Michigan United Traction Co. ....	Jackson .....	Sec. 25, Delhi Twp., Mason and Haslett.
Warner, Mr. ....	Mason .....	N. W. Cor. Sec. 36, Aurelius Twp.
Williams, C. W. ....	Williamston .....	Sec. 35, Williamston Twp.
Winters, J. P. ....	Leslie or Stockbridge. ....	Sec. 2, Bunker Hill Twp.
Graves, Frank. ....	Williamston .....	Williamston.
<i>Ionia County:</i>		
Crawford, Geo. W. ....	Ionia, R. F. D. 3. ....	Ionia.
Ionia Cement Products Co. ....	Ionia .....	Ionia.
Larsen, Geo. ....	Greenville, R. F. D. 3. ....	Greenville.
Miller, Henry. ....	East Main St., Ionia. ....	Ionia.
Normington, Frank. ....	Ionia, R. F. D. 1. ....	Ionia.

SAND AND GRAVEL PRODUCERS, 1914.—Continued.

Operator.	Office.	Pit.
<i>Ionia County—Con.</i>		
Fellows, Jas. M.	Lake Odessa	Lake Odessa.
Hauserman, Herman	Lake Odessa, R. F. D.	Lake Odessa.
Millard, Seymour	Palo	Palo.
Ronald Twp. Gravel Pit	Palo	Palo.
Griever, Mrs.	Saranac, R. F. D. 12	Saranac.
Keyser, Chas.	Saranac, R. F. D. 10	Saranac.
<i>Iosco County:</i>		
Boomer & Son, Jno	Tawas City	Tawas City.
Davison, Thos	Tawas City	Tawas City.
Kimball, Ray	Crystal Falls	Crystal Falls.
Chicago, Milwaukee & St. Paul R. R.	Chicago	Crystal Falls.
<i>Isabella County:</i>		
Winans, Frank	Blanchard	Blanchard.
Himebaugh, Geo.	Mt Pleasant	Mt. Pleasant.
Coughlin, Will	Shepherd, R. F. D. 1	Shepherd.
Dexter, James	Shepherd	Shepherd.
<i>Jackson County:</i>		
Greenville Gravel Co.	Greenville	Ackerman Lake.
Cooper, Alfred	Horton	Horton.
Winters, J. P.	Jackson	Jackson.
Cavanaugh, Wm	Horton	Horton.
Blackmarr, Chas.	107 Stewart Ave., Jackson	Jackson.
Blake, Wm	Jackson, R. F. D. 6	Jackson.
Emmons, Wm. P.	123 Clinton St., Jackson	Jackson.
Meyers, Albert	Jackson, R. F. D. 6	Jackson.
Watts, C. R.	Jackson, R. F. D. 2	Jackson.
Anderson, F. L.	Parma	Parma.
Bern, C. E.	Parma	Parma.
Mich. Central R. R. Co.	Detroit	Bloomerville.
Mich. United Traction Co.	Jackson	Michigan City.
Hunn, G. L.	Parma	Parma.
<i>Kalamazoo County:</i>		
Mich. United Traction Co.	Jackson	Augusta.
Miller, J. B.	Augusta	Augusta.
Balch, Wm. A.	Kalamazoo	Kalamazoo.
Balch, Uriel K.	Kalamazoo	Kalamazoo.
Buurma, Sam'l H.	Kalamazoo	Kalamazoo.
Haas & Son, A.	Kalamazoo	Kalamazoo.
Huff, Archie	Kalamazoo	Kalamazoo.
Klepper, Jacob	Kalamazoo	Kalamazoo.
Molhark, Peter	Kalamazoo	Kalamazoo.
Owens, Michael	Kalamazoo	Kalamazoo.
Russell, Jas. T.	Kalamazoo	Kalamazoo.
So. Mich. Brick Co.	Kalamazoo	Richland Twp.
Mich. United Traction Co.	Jackson	Kalamazoo.
Chadderton, Emery	Richland	Richland.
Gunn, J. W.	Watervliet	Williams.
<i>Kalkaska County:</i>		
Myers, Fred	Williams	Williams.
Anderson, Lind	Kalkaska	Kalkaska.
Hayward, W. F.	South Boardman	South Boardman.
<i>Kent County:</i>		
Holt, C. E.	Ada, R. F. D. 42	Ada.
Deiss, Jos.	Ada, R. F. D. 17	Alpine.
Reed, Percy	Alpine	Alpine.
Brewer, Earl	Byron Center, R. F. D.	Byron Center.
Battjes Fuel & Bldg. Mat. Co.	Grand Rapids	Grand Rapids.
Bunker Co., G. W.	Grand Rapids	Grand Rapids.
Harrison Land Co., Ltd.	Grand Rapids	Grand Rapids.
Carpenter & Anderson	Grand Rapids	Grand Rapids.
Pinyon, S. G.	Grand Rapids	Grand Rapids.
Valley City Stone & Gravel Co.	Grand Rapids	Grand Rapids.
Ide, D. K.	Grandville	Grandville.
Maloney, Pat	Harvard, R. F. D. 40	Harvard.
Holmgren, E. A.	Kent City	Kent City.
Kruger, M.	Kent City	Kent City.
Ryno, M. J.	Ross, R. F. D.	Ross.
Farnam, Reuben	Sand Lake	Sand Lake.
Kilts, Henry	Sand Lake	Sand Lake.
Standard Builders Supply Co.	Grand Rapids	Grand Rapids.
General Builders Supply Co.	Grand Rapids	Grand Rapids.

## SAND AND GRAVEL PRODUCERS, 1914.—Continued.

Operator.	Office.	Plt.
<b>Lake County:</b>		
Saunders & Co., G. W.	Chase	Chase.
<b>Lapeer County:</b>		
Hallock, Roy P.	Almont	Almont.
Miteen, Fred	Goodrich	Goodrich.
Caley, M.	Metamora	Hunters Creek.
<b>Leelanau County:</b>		
Bronson, Margaret	Maple City, R. F. D. 1	Maple City.
<b>Lenawee County:</b>		
Shannon, F. J.	Adrian	Adrian.
Smith, Porter C.	Clinton	Clinton.
Fuller, Charlie	Hudson	Hudson.
Lockwood, Sam	Hudson	Hudson.
Lowe, Frank	Hudson	Hudson.
Evans, Geo.	N. Morenci	N. Morenci.
Gillispie, R. P.	Tecumseh	Tecumseh.
Wilson, Ira	Tecumseh, R. F. D. 3	Tecumseh.
Tecumseh Gravel Co.	Tecumseh	Tecumseh.
<b>Livingston County:</b>		
Ohio & Michigan Sand & Gravel Co.	1025 Nicholas Bldg., Toledo, Ohio	Chilson.
Coles, Ben.	Fowlerville	Fowlerville.
Arnold, O. B.	Gregory	Gregory.
Butler, Dwight	Hamburg	Hamburg.
Hosby, E. B.	Howell	Howell.
Thomas, Henry	Oak Grove	Oak Grove.
<b>Macomb County:</b>		
Horning Gravel Co.	412 Weadlock Bldg., Saginaw	Armada.
Pratt, Ben J.	Armada	Armada.
Ruff, Michael	Lenox, R. D.	Lenox.
Chapman, Jas.	Memphis	Memphis.
Lake Side Ice & Coal Co.	Mt. Clemens	Mt. Clemens.
Harder, Henry	Richmond	Richmond.
Wacker, H. Jacob	Mt. Clemens	Mt. Clemens.
Savedore, Jos.	Utica, R. F. D. 2	Utica.
Detroit Sand & Gravel Co.	34 McGraw Bldg., Detroit	Utica.
Superior Sand & Gravel Co.	Detroit	Utica.
<b>Manistee County:</b>		
Hansen, Chris	Manistee	Manistee.
Hubbell Sand Co.	Manistee	Manistee.
Miller Bros. & Co.	Manistee	Manistee.
Summerfield, Porter M.	Manistee	Manistee.
Farr, M. A.	Onekama	Onekama.
McMartin, Chas.	Chief, R. F. D. 2	Chief.
Johnson, John	Chief	Chief.
<b>Marquette County:</b>		
Cleveland Cliffs Iron Co.	Ishpeming	Ishpeming.
Chicago & N. W. R. R.	Chicago	Michigamme.
<b>Mason County:</b>		
Hall, Ed.	Custer, R. F. D. 2	Custer.
Szymanski, Geo.	Freesoil, R. F. D. 2	Freesoil.
Wahr, John	Freesoil, R. F. D. 2	Freesoil.
Beaune, Oliver	Ludington, Box 68	Ludington.
Clark, Henry	Ludington	Ludington.
Lorentz, Ferdinand	Ludington	Ludington.
Dodge, C. C.	Tallman	Tallman.
Edmonson, James	Tallman	Tallman.
<b>Mecosta County:</b>		
Conklin, Wm.	Big Rapids, R. F. D. 5	Big Rapids.
Riley, J. E.	Millbrook, R. F. D. 2	Millbrook.
<b>Menominee County:</b>		
Schoen, Jno. A.	Wilson	Wilson.
Chicago & N. W. R. R.	Chicago	Daggett.

## SAND AND GRAVEL PRODUCERS, 1914.—Continued.

Operator.	Office.	Pit.
<b>Midland County:</b>		
Troyer, D. J.	Brier	Brier.
Gehoski, Mike	Midland, R. F. D. 1	Midland.
<b>Missaukee County:</b>		
Pickering, O. L.	Lake City	Lake City.
Reeves, Kary D.	McLean, Ill.	McBain.
<b>Monroe County:</b>		
Falmstock, Emerson	Carlton	Carlton.
Stoeckert, Wm.	Monroe	Monroe.
National Silica Co.	Steiner	Steiner.
<b>Montcalm County:</b>		
Belknap Cement Products Co.	Greenville	Greenville.
Boezwinkle, Wm.	Pierson	Pierson.
Matz, Chas.	Pierson	Pierson.
Tissue, Lenn	Stanton, R. F. D. 1	Stanton.
Sinkey, Mrs. L. M.	Carson City	Carson City.
Larsen, Geo.	Greenville, R. F. D. 3	Greenville.
Williams, E. O.	Edmore	Edmore.
<b>Muskegon County:</b>		
Bettis, Phil	Ravenna, R. F. D.	Ravenna.
Homer, Wm.	Ravenna, R. F. D.	Ravenna.
Valley, Edw.	Twin Lakes	Twin Lakes.
<b>Newaygo County:</b>		
Wentland, Mrs. Johanna	Woodville	Woodville.
Hall, A. E.	Newaygo	Newaygo.
Nieboer, J.	Grant	Grant.
Raymond, R. J.	Grant	Grant.
<b>Oakland County:</b>		
Heberson Bros.	Birmingham	Birmingham.
Park & Son, A. H.	Birmingham, R. F. D. 2	Birmingham.
Mich. Portland Cement Paving Co.	Griswold St., Detroit	Clarkston.
Ely, C.	Farmington	Farmington.
Rice, E. J.	New Hudson	New Hudson.
Campbell, John	Ortonville, R. F. D. 2	Ortonville.
Detroit-Oxford Gravel & Stone Co.	Oxford	Oxford.
Bartlett, C. S.	Pontiac	Pontiac.
Kemp, W. H.	Pontiac	Pontiac.
Rockwell, C. L.	Pontiac	Pontiac.
Slater Construction Co.	Pontiac	Pontiac.
Heal, Geo.	669 Baker St., Detroit	Rochester.
Rochester Sand & Brick Co.	Detroit	Rochester.
Boomer Sand & Gravel Co.	520 Forest St. E., Detroit.	Rochester.
<b>Oceana County:</b>		
Aldrich, A. O.	Crystal Valley	Crystal Valley.
Golden Twp. Pit	Mears	Mears.
Twp. Board of Newfield	Hesperia	Hesperia.
Cartright, Thos.	Rothbury, R. F. D. 1	Rothbury.
Whele, Frank	Rothbury, R. F. D. 1	Rothbury.
<b>Ogemaw County:</b>		
Edwards, John	Prescott	Prescott.
Brooks, H. F.	Rose City	Rose City.
Harvey, D.	West Branch, R. F. D. 1	West Branch.
<b>Oscola County:</b>		
Carmichael, Ed.	Evart, R. F. D. 1	Evart.
White & Day	Evart	Evart.
Stone, Chas. E.	Hersey, R. F. D. 1	Hersey.
Woodward, Carl	Hersey, R. F. D. 1	Hersey.
Hoogerhide, Jno.	Reed City, R. F. D. 6	Reed City.
Marvin, Seymour	Tustin, R. F. D. 1	Tustin.
<b>Ottawa County:</b>		
Holthrop, Jno.	Ferrysburg	Ferrysburg.
Graham, Mrs. T.	Grand Haven	Grand Haven.
Walsma & Co.	Grand Haven	Grand Haven.
Van Weelden & Co., J.	609 Fulton St., Grand Haven	Grand Haven.

## SAND AND GRAVEL PRODUCERS, 1914.—Continued.

Operator.	Office.	Pit.
<i>Presque Isle County:</i>		
Kroll, Andrew.....	Posen.....	Posen.
<i>Roscommon County:</i>		
Campbell Gravel Co.....	Roscommon.....	Roscommon.
Cresswell, Thos. B.....	Saginaw.....	Riverbend (Saginaw).
Molles, C. B.....	Saginaw.....	Saginaw River.
<i>St. Clair County:</i>		
Armitage, Sidney.....	Atkins, R. F. D. 1.....	Atkins.
Chapman, Jas.....	Memphis.....	
Kinney, Frank.....	Atkins, R. F. D. 1.....	Atkins.
Snyder, Wm.....	Atkins, R. F. D. 1.....	Atkins.
Kitchen, Cyrenius.....	Smiths Creek.....	Goodells.
McGennett, Jas.....	Smiths Creek.....	Smiths Creek.
Westrick & Son, C. A.....	Marine City.....	Marine City.
Caldwells Sand & Gravel Co.....	Windsor, Ont.....	Port Huron.
Jacques & Sons, E.....	Foot of 1st St., Duluth, Minn.....	Port Huron.
Marine Contracting Co.....	211 Quay St., Port Huron	Port Huron.
<i>St. Joseph County:</i>		
Hill, S.....	Colon.....	Colon.
Wade, H. H.....	White Pigeon.....	White Pigeon.
<i>Sanilac County:</i>		
David McKillen.....	Brown City.....	Brown City.
Swaffler, Chas.....	Deckerville.....	Deckerville.
Buck, C. J.....	Marlette.....	Marlette.
Gilbert, Geo.....	Melvin, R. F. D. 6.....	Melvin.
Miller, Henry.....	Minden City.....	Minden City.
Dawson & Son.....	Sandusky.....	Sandusky.
<i>Shiawassee County:</i>		
Barnes, Olin.....	Byron.....	Byron.
Graham, John.....	Byron.....	Byron.
Shannon, A. E.....	Byron.....	Byron.
Van Campen, C.....	Henderson.....	Henderson.
Schultz, A. A.....	Laingsburg.....	Laingsburg.
<i>Tuscola County:</i>		
Hill, Tom.....	Caro.....	Caro.
Consolidated Coal Co.....	Saginaw.....	
Baker, Gilbert.....	Kingston.....	Kingston.
Whittaker, Benson.....	Kingston.....	Kingston.
Donigan, Joseph.....	Millington.....	Millington.
Scott, Wm.....	Reese, R. F. D. 1.....	Reese.
Hill, Elmer A.....	Unionville.....	Silverwood.
<i>Van Buren County:</i>		
Burger, F. A.....	Bangor.....	Bangor.
Hopplin, A. D.....	Bangor.....	Bangor.
Shine, John.....	Bangor.....	Bangor.
McKee, Jr., Darwin.....	Decatur.....	Decatur.
Orr, James.....	Decatur.....	Decatur.
Sherburn, John.....	Decatur.....	Decatur.
Otis, L. L.....	Kibble.....	Kibble.
Hunt, Geo.....	Lawrence.....	Lawrence.
Fry, W. G.....	South Haven.....	South Haven.
<i>Washtenaw County:</i>		
City Concrete & Coal Co.....	1015 Dime Bank Bldg., Detroit.....	Delhi.
Eddie, Geo.....	Ann Arbor, R. F. D. 8.....	Ann Arbor.
Fiegel, Fred.....	Ann Arbor, R. F. D. 3.....	Ann Arbor.
Pease, Wm.....	Saline, R. F. D.....	Saline.
Youngs, Ed.....	Saline, R. F. D.....	Saline.
Crane, Mortimer R.....	217 Mich. St., Ypsilanti.....	Ypsilanti.
Elsifor, S. A.....	117 First St., Ann Arbor.....	Ann Arbor.
Lake Shore & Mich. So. R. R. Co.....		Manchester.
Mich. Central R. R. Co.....	Detroit.....	Osborne Pit.
Washed Clean Sand & Gravel Co.....	Ann Arbor.....	Dexter.

SAND AND GRAVEL PRODUCERS, 1914.—*Concluded.*

Operator.	Office.	Pit.
<i>Wayne County:</i>		
Detroit United Fuel & Supply Co. ....	Detroit, Free Press Bldg.	Utica and Detroit.
Mich. Builders Supply Co. ....	Detroit	Detroit.
Wabash R. R. Co., American Silica Co. ....	Rockwood	Rockwood.
Thompson, W. R. ....	Detroit, 606 Kress Bldg.	Detroit.
<i>Washtenaw County:</i>		
Selma Twp. Pit	Cadillac	Cadillac.
Fewless, John	Manton, R. F. D. 3	Manton.

TRAP ROCK PRODUCERS, 1914.

Operator.	Office.	Quarry.
<i>Marquette County:</i>		
Durocher, T. L. ....	Marquette	Marquette.
Marquette Stone Co. ....	Marquette	Marquette.
The Park Cemetery Stone Co. ....	Marquette	Marquette.
City of Negaunee	Negaunee	Negaunee.
Marquette Trap Rock Co. ....	Marquette	Marquette.
<i>Houghton County:</i>		
Winona Copper Co. ....	Winona	Winons.



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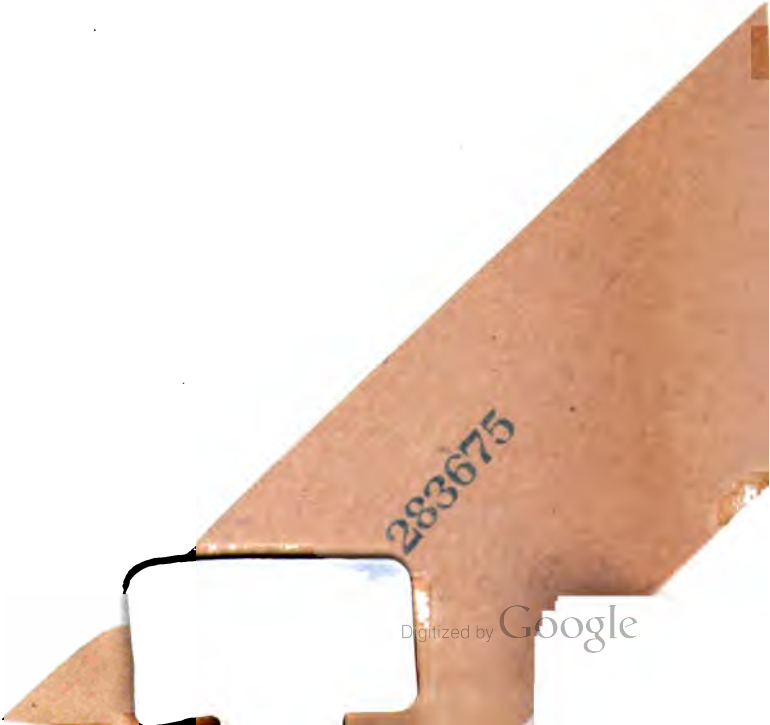
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